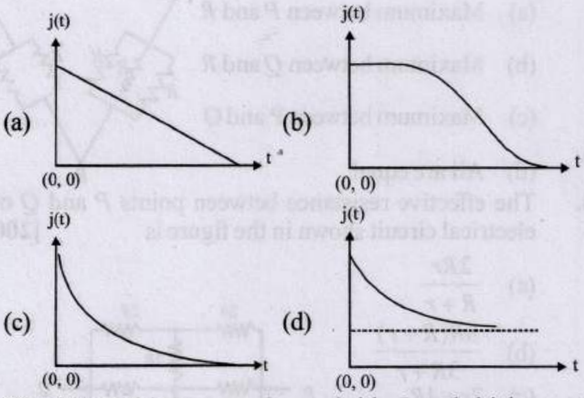
Chapter
Current Electricity

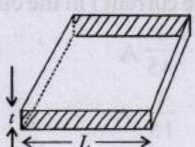
Topic-1: Electric Current, Drift of Electrons, Ohm's Law, Resistance and Resistivity

1 MCQs with One Correct Answer

1. An infinite line charge of uniform electric charge density λ lies along the axis of an electrically conducting infinite cylindrical shell of radius R. At time t = 0, the space inside the cylinder is filled with a material of permittivity ε and electrical conductivity σ. The electrical conduction in the material follows Ohm's law. Which one of the following graphs best describes the subsequent variation of the magnitude of current density j(t) at any point in the material? **[Adv. 2016]**

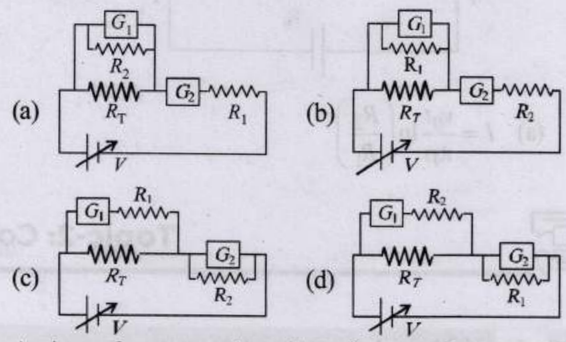


2. Consider a thin square sheet of side L and thickness t, made of a material of resistivity ρ. The resistance between two opposite faces, shown by the shaded areas in the figure is **[2010]**



(a) directly proportional to L
(b) directly proportional to t
(c) independent of L
(d) independent of t

3. To verify Ohm's law, a student is provided with a test resistor R_T, a high resistance R_1, a small resistance R_2, two identical galvanometers G_1 and G_2, and a variable voltage source V. The correct circuit to carry out the experiment is **[2010]**

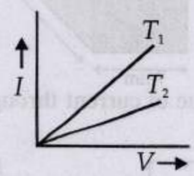


4. A piece of copper and another of germanium are cooled from room temperature to 80° K. The resistance of **[1988 - 1 Mark]**
(a) each of them increases
(b) each of them decreases
(c) copper increases and germanium decreases
(d) copper decreases and germanium increases

5. The temperature coefficient of resistance of a wire is 0.00125 per °C. At 300 K, its resistance is 1 ohm. This resistance of the wire will be 2 ohm at. **[1980]**
(a) 1154 K (b) 1100 K (c) 1400 K (d) 1127 K

5 True / False

6. The current –voltage graphs for a given metallic wire at two different temperatures T_1 and T_2 are shown in the figure. **[1985 - 3 Marks]**

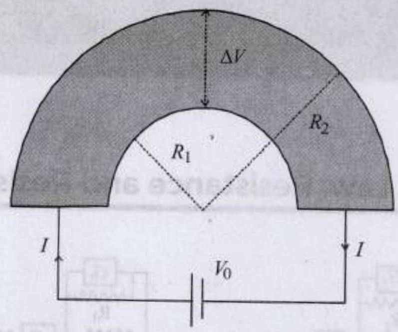


The temperature T_2 is greater than T_1.

7. Electrons in a conductor have no motion in the absence of a potential difference across it. **[1982 - 2 Marks]**

6 MCQs with One or More than One Correct Answer

8. Shown in the figure is a semicircular metallic strip that has thickness t and resistivity ρ. Its inner radius is R_1 and outer radius is R_2. If a voltage V_0 is applied between its two ends, a current I flows in it. In addition, it is observed that a transverse voltage ΔV develops between its inner and outer surfaces due to purely kinetic effects of moving electrons (ignore any role of the magnetic field due to the current). Then (figure is schematic and not drawn to scale) **[Adv. 2020]**



(a) $I = \frac{V_0 t}{\pi\rho}\ln\left(\frac{R_2}{R_1}\right)$

(b) the outer surface is at a higher voltage than the inner surface

(c) the outer surface is at a lower voltage than the inner surface

(d) $\Delta V \propto I^2$

9 Assertion and Reason Type Questions

9. Read the following statements carefully: **[1993-2 Marks]**

Y: The resistivity of a semiconductor decreases with increase of temperature.

Z: In a conducing solid, the rate of collisions between free electrons and ions increases with increase of temperature

Select the correct statement(s) from the following;

(a) Y is true but Z is false
(b) Y is false but Z is true
(c) Both Y and Z are true
(d) Y is true and Z is the correct reason for Y

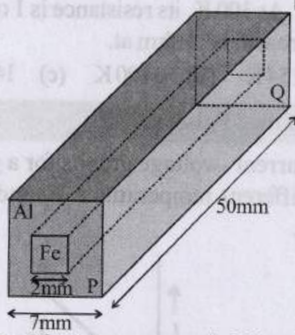
10 Subjective Problems

10. If a copper wire is stretched to make it 0.1% longer what is the percentage change in its resistance? **[1978]**

Topic-2: Combination of Resistances

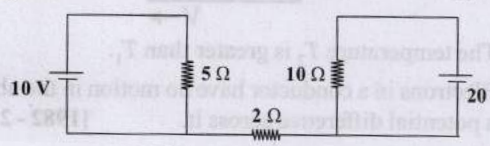
1 MCQs with One Correct Answer

1. In an aluminium (Al) bar of square cross section, a square hole is drilled and is filled with iron (Fe) as shown in the figure. The electrical resistivities of Al and Fe are 2.7×10^{-8} Ω m and 1.0×10^{-7} Ω m, respectively. The electrical resistance between the two faces P and Q of the composite bar is **[Adv. 2015]**



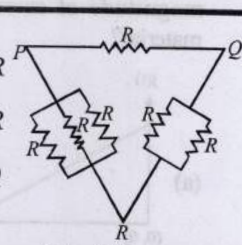
(a) $\frac{2475}{64}$ μΩ
(b) $\frac{1875}{64}$ μΩ
(c) $\frac{1875}{49}$ μΩ
(d) $\frac{2475}{132}$ μΩ

2. Find out the value of current through 2Ω resistance for the given circuit. **[2005S]**



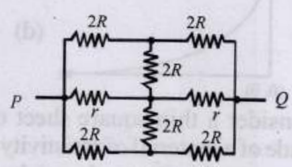
(a) zero (b) $2A$ (c) $5A$ (d) $4A$

3. Six identical resistors are connected as shown in the figure. The equivalent resistance will be **[2004S]**



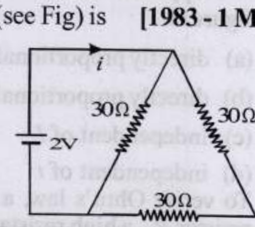
(a) Maximum between P and R
(b) Maximum between Q and R
(c) Maximum between P and Q
(d) All are equal

4. The effective resistance between points P and Q of the electrical circuit shown in the figure is **[2002S]**



(a) $\frac{2Rr}{R+r}$
(b) $\frac{8R(R+r)}{3R+r}$
(c) $2r+4R$
(d) $\frac{5R}{2}+2r$

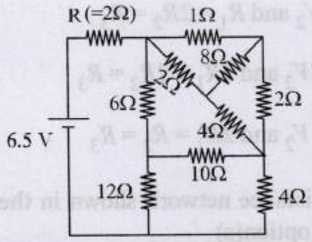
5. The current i in the circuit (see Fig) is **[1983 - 1 Mark]**



(a) $\frac{1}{45}$ A
(b) $\frac{1}{15}$ A
(c) $\frac{1}{10}$ A (d) $\frac{1}{5}$ A

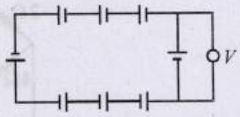
2 Integer Value Answer

6. In the following circuit, the current through the resistor R (= 2 Ω) is I amperes. The value of I is **[Adv. 2015]**

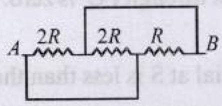


4 Fill in the Blanks

7. In the circuit shown below, each battery is 5V and has an internal resistance of 0.2 ohm. The reading in the ideal voltmeter V is ..... V. **[1997 - 2 Marks]**

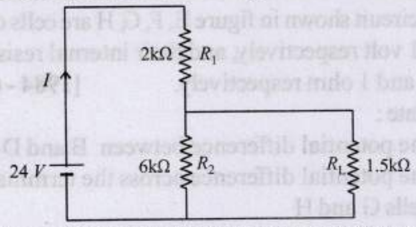


8. The equivalent resistance between points A and B of the circuit given below is ..... Ω. **[1997 - 2 Marks]**



6 MCQs with One or More than One Correct Answer

9. For the circuit shown in the figure **[2009]**



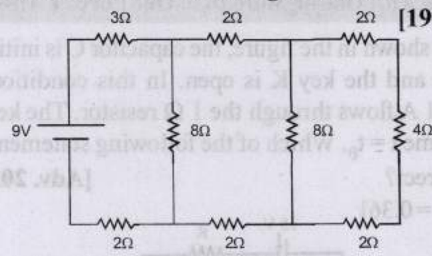
(a) the current I through the battery is 7.5 mA

(b) the potential difference across R_L is 18 V

(c) ratio of powers dissipated in R_1 and R_2 is 3

(d) if R_1 and R_2 are interchanged, magnitude of the power dissipated in R_L will decrease by a factor of 9

10. In the circuit shown in Figure the current through **[1998S - 2 Marks]**



(a) the 3 Ω resistor is 0.50 A.

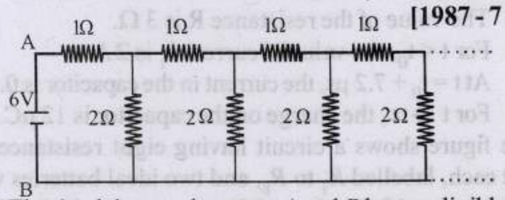
(b) the 3 Ω resistor is 0.25 A.

(c) the 4 Ω resistor is 0.50 A

(d) the 4 Ω resistor is 0.25 A.

10 Subjective Problems

11. An infinite ladder network of resistances is constructed with a 1 ohm and 2 ohm resistances, as shown in fig. **[1987 - 7 Marks]**

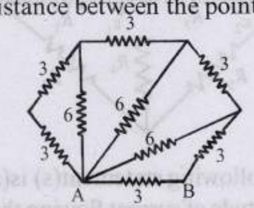


The 6 volt battery between A and B has negligible internal resistance :

(i) Show that the effective resistance between A and B is 2 ohms.

(ii) What is the current that passes through the 2 ohm resistance nearest to the battery ?

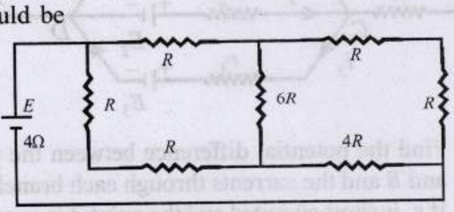
12. All resistances in the diagram below are in ohms. Find the effective resistance between the points A and B. **[1979]**



Topic-3: Krichhoff's Laws, Cells, Thermo e.m.f. & ELectrolysis

1 MCQs with One Correct Answer

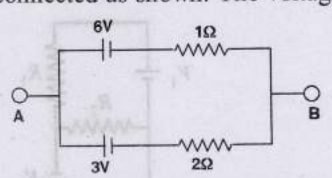
1. A battery of internal resistance 4Ω is connected to the network of resistances as shown. In order that the maximum power can be delivered to the network, the value of R in Ω should be **[1995S]**



(a) $\frac{4}{9}$ (b) 2 (c) $\frac{8}{3}$ (d) 18

2 Integer Value Answer

2. Two batteries of different emfs and different internal resistances are connected as shown. The voltage across AB in volts is **[2011]**

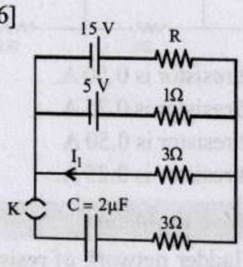


5 True / False

3. In an electrolytic solution the electric current is mainly due to the movement of free electrons. **[1980]**

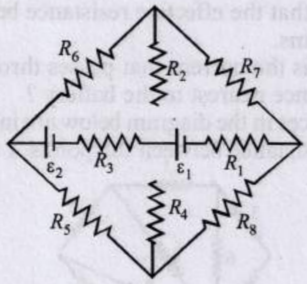
6 MCQs with One or More than One Correct Answer

4. In a circuit shown in the figure, the capacitor C is initially uncharged and the key K is open. In this condition, a current of 1 A flows through the 1 Ω resistor. The key is closed at time $t = t_0$. Which of the following statement(s) is (are) correct? **[Adv. 2023]**
[Given: $e^{-1} = 0.36$]



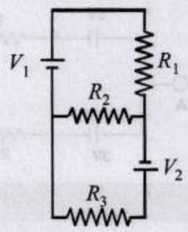
(a) The value of the resistance R is 3 Ω.
(b) For $t < t_0$, the value of current I_1 is 2 A.
(c) At $t = t_0 + 7.2$ μs, the current in the capacitor is 0.6 A.
(d) For $t \to \infty$, the charge on the capacitor is 12 μC.

5. The figure shows a circuit having eight resistances of 1 Ω each, labelled R_1 to R_8, and two ideal batteries with voltages $\varepsilon_1 = 12$ V and $\varepsilon_2 = 6$ V. **[Adv. 2022]**



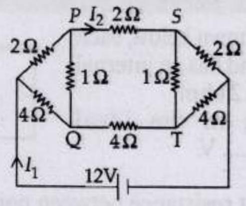
Which of the following statement(s) is(are) correct?
(a) The magnitude of current flowing through R_1 is 7.2 A.
(b) The magnitude of current flowing through R_2 is 1.2 A.
(c) The magnitude of current flowing through R_3 is 4.8 A.
(d) The magnitude of current flowing through R_5 is 2.4 A.

6. Two ideal batteries of emf V_1 and V_2 and three resistances R_1, R_2 and R_3 are connected as shown in the figure. The current in resistance R_2 would be zero if **[Adv. 2014]**



(a) $V_1 = V_2$ and $R_1 = R_2 = R_3$
(b) $V_1 = V_2$ and $R_1 = 2R_2 = R_3$
(c) $V_1 = 2V_2$ and $2R_1 = 2R_2 = R_3$
(d) $2V_1 = V_2$ and $2R_1 = R_2 = R_3$

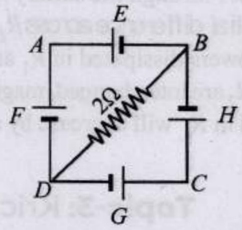
7. For the resistance network shown in the figure, choose the correct option(s) **[2012-I]**



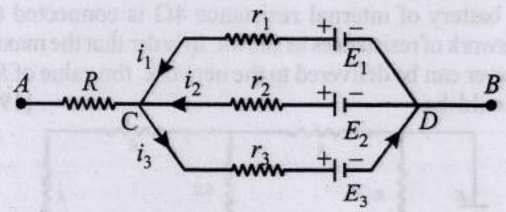
(a) The current through PQ is zero.
(b) $I_1 = 3$A
(c) The potential at S is less than that at Q.
(d) $I_2 = 2$A

10 Subjective Problems

8. In the circuit shown in figure E, F, G, H are cells of emf 2, 1, 3 and 1 volt respectively, and their internal resistances are 2, 1, 3 and 1 ohm respectively. **[1984 - 6 Marks]**
Calculate :
(i) the potential difference between B and D and
(ii) the potential difference across the terminals of each cells G and H



9. In the circuit shown in fig $E_1 = 3$ volts, $E_2 = 2$ volts, $E_3 = 1$ volt and $R = r_1 = r_2 = r_3 = 1$ ohm. **[1981 - 6 Marks]**



(i) Find the potential difference between the points A and B and the currents through each branch.
(ii) If r_2 is short circuited and the point A is connected to point B, find the currents through E_1, E_2 E_3 and the resistor R.

Topic-4: Heating Effect of Current

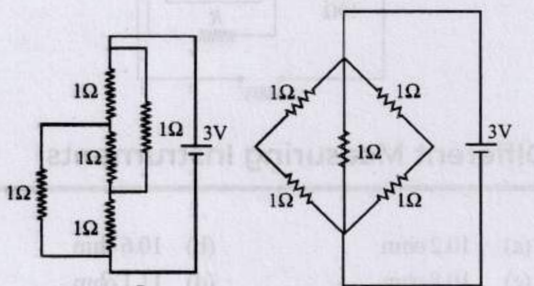
1 MCQs with One Correct Answer

1. Incandescent bulbs are designed by keeping in mind that the resistance of their filament increases with the increase in temperature. If at room temperature, 100 W, 60 W and 40 W bulbs have filament resistances R_{100}, R_{60} and R_{40}, respectively, the relation between these resistances is **[2010]**

(a) $\frac{1}{R_{100}} = \frac{1}{R_{40}} + \frac{1}{R_{60}}$ (b) $R_{100} = R_{40} + R_{60}$

(c) $R_{100} > R_{60} > R_{40}$ (d) $\frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$

2. Figure shows three resistor configurations R_1, R_2 and R_3 connected to 3V battery. If the power dissipated by the configuration R_1, R_2 and R_3 is P_1, P_2 and P_3, respectively, then – **[2008]**



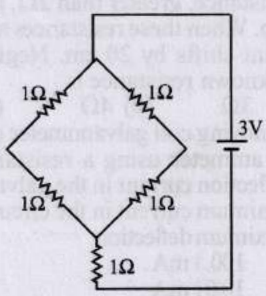
R_1 R_2

(a) $P_1 > P_2 > P_3$

(b) $P_1 > P_3 > P_2$

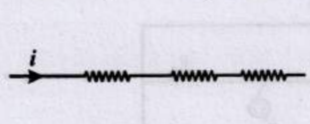
(c) $P_2 > P_1 > P_3$

(d) $P_3 > P_2 > P_1$

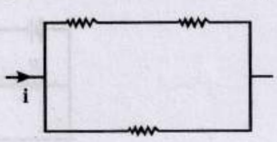


R_3

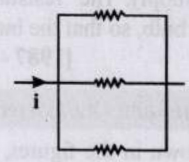
3. The three resistance of equal value are arranged in the different combinations shown below. Arrange them in increasing order of power dissipation. **[2003S]**



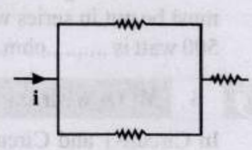
(I)



(II)



(III)

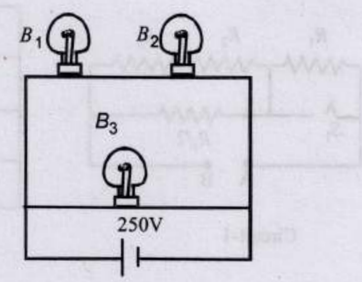


(IV)

(a) III < II < IV < I (b) II < III < IV < I

(c) I < IV < III < II (d) I < III < II < IV

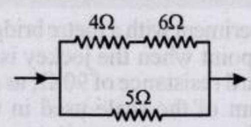
4. A 100 W bulb B_1, and two 60 W bulb B_2 and B_3, are connected to a 250 V source, as shown in figure. Now W_1, W_2 and W_3 are the output powers of the bulbs B_1, B_2 and B_3, respectively. Then **[2002S]**



(a) $W_1 > W_2 = W_3$ (b) $W_1 > W_2 > W_3$

(c) $W_1 < W_2 = W_3$ (d) $W_1 < W_2 < W_3$

5. In the circuit shown in fig the heat produced in the 5 ohm resistor due to the current flowing through it is 10 calories per second. **[1981- 2 Marks]**



The heat generated in the 4 ohms resistor is

(a) 1 calorie / sec (b) 2 calories /sec

(c) 3 calories /sec (d) 4 calories /sec

6. A constant voltage is applied between the two ends of a uniform metallic wire. Some heat is developed in it. The heat developed is doubled if **[1980]**

(a) both the length and the radius of the wire are halved.

(b) both the length and the radius of the wire are doubled.

(c) the radius of the wire is doubled.

(d) the length of the wire is doubled.

2 Integer Value Answer

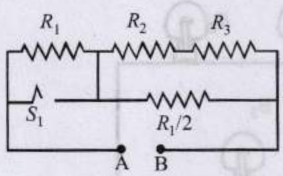
7. When two identical batteries of internal resistance 1Ω each are connected in series across a resistor R, the rate of heat produced in R is J_1. When the same batteries are connected in parallel across R, the rate is J_2. If $J_1 = 2.25\ J_2$ then the value of R in Ω is **[2010]**

4 Fill in the Blanks

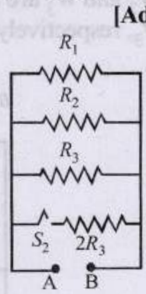
8. An electric bulb rated for 500 watts at 100 volts is used in a circuit having a 200 volts supply. The resistance R that must be put in series with the bulb, so that the bulb delivers 500 watt is ....ohm. **[1987 - 2 Marks]**

6 MCQs with One or More than One Correct Answer

9. In Circuit-1 and Circuit-2 shown in the figures, $R_1 = 1\ \Omega$, $R_2 = 2\ \Omega$ and $R_3 = 3\Omega$.
P_1 and P_2 are the power dissipations in Circuit-1 and Circuit-2 when the switches S_1 and S_2 are in open conditions, respectively.
Q_1 and Q_2 are the power dissipations in Circuit-1 and Circuit-2 when the switches S_1 and S_2 are in closed conditions, respectively. **[Adv. 2022]**



Circuit-1



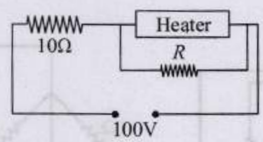
Circuit-2

Which of the following statement(s) is(are) correct?
(a) When a voltage source of 6 V is connected across A and B in both circuits, $P_1 < P_2$.
(b) When a constant current source of 2 Amp is connected across A and B in both circuits, $P_1 > P_2$.
(c) When a voltage source of 6 V is connected across A and B in Circuit-1, $Q_1 > P_1$.
(d) When a constant current source of 2 Amp is connected across A and B in both circuits, $Q_2 < Q_1$.

10. Heater of an electric kettle is made of a wire of length L and diameter d. It takes 4 minutes to raise the temperature of 0.5 kg water by 40 K. This heater is replaced by a new heater having two wires of the same material, each of length L and diameter $2d$. The way these wires are connected is given in the options. How much time in minutes will it take to raise the temperature of the same amount of water by 40 K? **[Adv. 2014]**
(a) 4 if wires are in parallel (b) 2 if wires are in series
(c) 1 if wires are in series (d) 0.5 if wires are in parallel

10 Subjective Problems

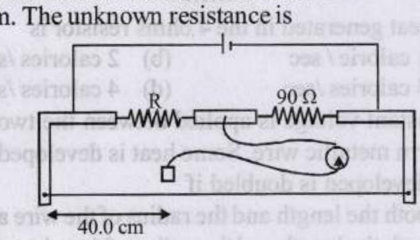
11. A heater is designed to operate with a power of 1000 watts in a 100 volt line. It is connected in a combinations with a resistance of 10 ohms and a resistance R to a 100 volts mains as shown in the figure. What should be the value of R so that the heater operates with a power of 62.5 watts. **[1978]**



Topic-5: Wheatstone Bridge and Different Measuring Instruments

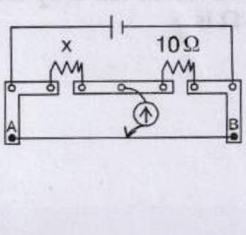
1 MCQs with One Correct Answer

1. During an experiment with a metre bridge, the galvanometer shows a null point when the jockey is pressed at 40.0 cm using a standard resistance of 90 Ω, as shown in the figure. The least count of the scale used in the metre bridge is 1mm. The unknown resistance is **[Adv. 2014]**



(a) $60 \pm 0.15\ \Omega$ (b) $135 \pm 0.56\ \Omega$
(c) $60 \pm 0.25\ \Omega$ (d) $135 \pm 0.23\ \Omega$

2. A meter bridge is set up as shown, to determine an unknown resistance 'X' using a standard 10 ohm resistor. The galvanometer shows null point when tapping-key is at 52 cm mark. The end-corrections are 1 cm and 2 cm respectively for the ends A and B. The determined value of 'X' is **[2011]**

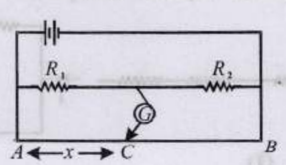


(a) 10.2 ohm (b) 10.6 ohm
(c) 10.8 ohm (d) 11.1 ohm

3. A resistance of 2Ω is connected across one gap of a metre-bridge (the length of the wire is 100 cm) and an unknown resistance, greater than 2Ω, is connected across the other gap. When these resistances are interchanged, the balance point shifts by 20 cm. Neglecting any corrections, the unknown resistance is **[2007]**
(a) 3Ω (b) 4Ω (c) 5Ω (d) 6Ω

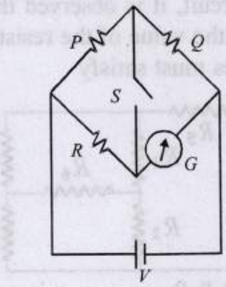
4. A moving coil galvanometer of resistance 100 Ω is used as an ammeter using a resistance 0.1 Ω. The maximum deflection current in the galvanometer is 100 μA. Find the minimum current in the circuit so that the ammeter shows maximum deflection **[2005S]**
(a) 100.1 mA (b) 1000.1 mA
(c) 10.01 mA (d) 1.01 mA

5. In the shown arrangement of the experiment of the meter bridge if AC corresponding to null deflection of galvanometer is x, what would be its value if the radius of the wire AB is doubled? **[2003S]**



(a) x (b) $x/4$
(c) $4x$ (d) $2x$

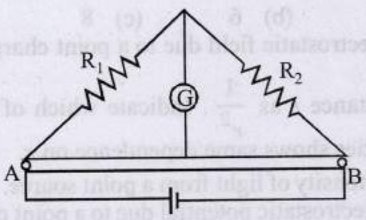
6. In the circuit $P \neq R$, the reading of the galvanometer is same with switch S open or closed. Then **[1999 - 2 Marks]**



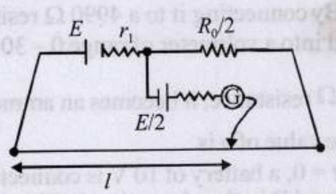
(a) $I_R = I_G$ (b) $I_P = I_G$
(c) $I_Q = I_G$ (d) $I_Q = I_R$

2 Integer Value Answer

7. Two resistances $R_1 = X\,\Omega$ and $R_2 = 1\,\Omega$ are connected to a wire AB of uniform resistivity, as shown in the figure. The radius of the wire varies linearly along its axis from 0.2 *mm* at A to 1 *mm* at B. A galvanometer (G) connected to the center of the wire, 50 *cm* from each end along its axis, shows zero deflection when A and B are connected to a battery. The value of X is **[Adv. 2022]**

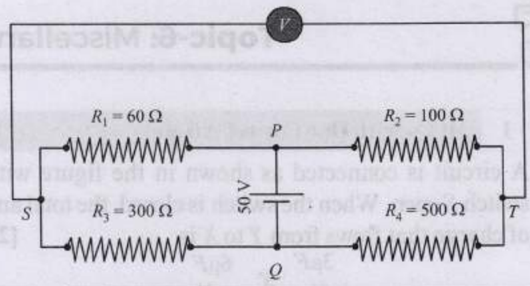


8. In order to measure the internal resistance r_1 of a cell of emf E, a meter bridge of wire resistance $R_0 = 50\,\Omega$, a resistance $R_0/2$, another cell of emf $E/2$ (internal resistance r) and a galvanometer G are used in a circuit, as shown in the figure. If the null point is found at $l = 72$ cm, then the value of $r_1 =$ ____ Ω. **[Adv. 2021]**



3 Numeric Answer

9. In the balanced condition, the values of the resistances of the four arms of a Wheatstone bridge are shown in the figure below. The resistance R_3 has temperature coefficient $0.0004°C^{-1}$. If the temperature of R_3 is increased by 100°C, the voltage developed between S and T will be ____ volt. **[Adv. 2020]**



9 Assertion and Reason Type Questions

10. **STATEMENT-1 :** In a Meter Bridge experiment, null point for an unknown resistance is measured. Now, the unknown resistance is put inside an enclosure maintained at a higher temperature. The null point can be obtained at the same point as before by decreasing the value of the standard resistance.

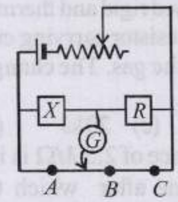
STATEMENT-2 : Resistance of a metal increases with increase in temperature. **[2008]**

(a) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1
(b) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(c) Statement -1 is True, Statement-2 is False
(d) Statement-1 is False, Statement-2 is True

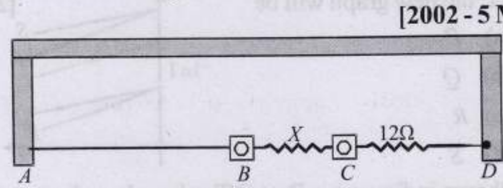
10 Subjective Problems

11. An unknown resistance X is to be determined using resistances R_1, R_2 or R_3. Their corresponding null points are A, B and C. Find which of the above will give the most accurate reading and why? **[2005 - 2 Marks]**

$R = R_1$ or R_2 or R_3



12. A thin uniform wire AB of length 1m, an unknown resistance X and a resistance of 12 Ω are connected by thick conducting strips, as shown in the figure. A battery and a galvanometer (with a sliding jockey connected to it) are also available. Connections are to be made to measure the unknown resistance X using the principle of Wheatstone bridge. Answer the following questions. **[2002 - 5 Marks]**

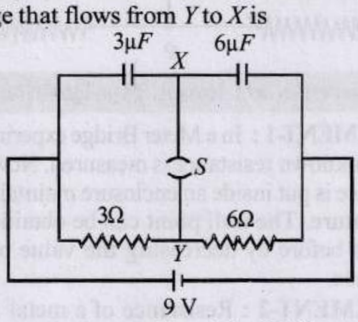


(a) Are there positive and negative terminals on the galvanometer?
(b) Copy the figure in your answer book and show the battery and the galvanometer (with jockey) connected at appropriate points.

Topic-6: Miscellaneous (Mixed Concepts) Problems

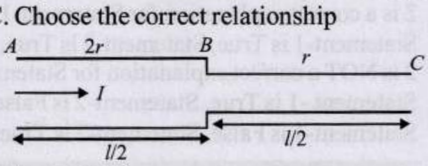
1 MCQs with One Correct Answer

1. A circuit is connected as shown in the figure with the switch S open. When the switch is closed, the total amount of charge that flows from Y to X is **[2007]**



(a) 0 (b) 54 μC (c) 27μC (d) 81 μC

2. If a steady current I is flowing through a cylindrical element ABC. Choose the correct relationship **[2006]**



(a) $V_{AB} = 2V_{BC}$
(b) Power across BC is 4 times the power across AB
(c) Current densities in AB and BC are equal
(d) Electric field due to current inside AB and BC are equal

3. An ideal gas is filled in a closed rigid and thermally insulated container. A coil of 100 Ω resistor carrying current 1 A for 5 minutes supplies heat to the gas. The change in internal energy of the gas is **[2005S]**

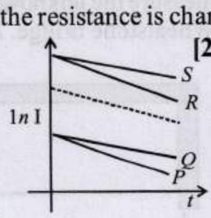
(a) 10 kJ (b) 30 kJ (c) 20 kJ (d) 0 kJ

4. A 4 μF capacitor, a resistance of 2.5 $M\Omega$ is in series with 12 V battery. Find the time after which the potential difference across the capacitor is 3 times the potential difference across the resistor. [Given $ln(2) = 0.693$] **[2005S]**

(a) 13.86s (b) 6.93s (c) 7s (d) 14s

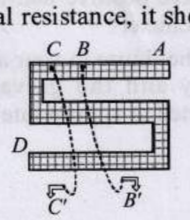
5. A capacitor is charged using an external battery with a resistance x in series. The dashed line shows the variation of ln I with respect to time. If the resistance is changed to $2x$, the new graph will be **[2004S]**

(a) P
(b) Q
(c) R
(d) S

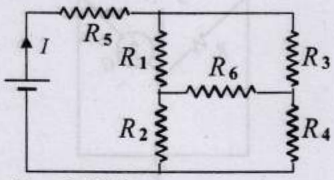


6. Shown in figure is a Post Office box. In order to calculate the value of external resistance, it should be connected between **[2004S]**

(a) B' and C'
(b) A and D
(c) C and D
(d) B and D



7. In the given circuit, it is observed that the current I is independent of the value of the resistance R_6. Then the resistance values must satisfy **[2001S]**



(a) $R_1R_2R_5 = R_3R_4R_6$
(b) $\dfrac{1}{R_5} + \dfrac{1}{R_6} = \dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3 + R_4}$
(c) $R_1R_4 = R_2R_3$
(d) $R_1R_3 = R_2R_4 = R_5R_6$

8. A wire of length L and 3 identical cells of negligible internal resistances are connected in series. Due to the current, the temperature of the wire is raised by ΔT in a time t. A number N of similar cells is now connected in series with a wire of the same material and cross-section but of length $2L$. The temperature of the wire is raised by the same amount ΔT in the same time t. the value of N is **[2001S]**

(a) 4 (b) 6 (c) 8 (d) 9

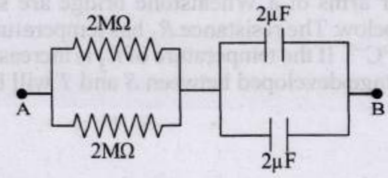
9. The electrostatic field due to a point charge depends on the distance r as $\dfrac{1}{r^2}$. Indicate which of the following quantities shows same dependence on r. **[1980]**

(a) Intensity of light from a point source.
(b) Electrostatic potential due to a point charge.
(c) Electrostatic potential at a distance r from the centre of a charged metallic sphere. Given $r <$ radius of the sphere.
(d) None of these

2 Integer Value Answer

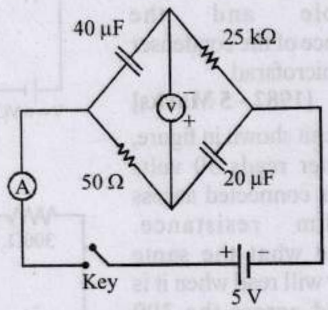
10. A galvanometer gives full scale deflection with 0.006 A current. By connecting it to a 4990 Ω resistance, it can be converted into a voltmeter of range 0 – 30 V. If connected to a $\dfrac{2n}{249}$ Ω resistance, it becomes an ammeter of range 0 – 1.5A. The value of n is **[Adv. 2014]**

11. At time $t = 0$, a battery of 10 V is connected across points A and B in the given circuit. If the capacitors have no charge initially, at what time (in sceonds) does the voltage across them become 4 V? [Take : $ln5 = 1.6$, $ln3 = 1.1$] **[2010]**



6 MCQs with One or More than One Correct Answer

12. In the circuit shown below, the key is pressed at time t = 0. Which of the following statement(s) is(are) true? **[Adv. 2016]**



(a) The voltmeter displays –5V as soon as the key is pressed, and displays +5V after a long time
(b) The voltmeter will display 0V at time t = ln 2 seconds
(c) The current in the ammeter becomes 1/e of the initial value after 1 second
(d) The current in the ammeter becomes zero after a long time.

13. An incandescent bulb has a thin filament of tungsten that is heated to high temperature by passing an electric current. The hot filament emits black–body radiation. The filament is observed to break up at random locations after a sufficiently long time of operation due to non–uniform evaporation of tungsten from the filament. If the bulb is powered at constant voltage, which of the following statement(s) is(are) true? **[Adv. 2016]**
(a) The temperature distribution over the filament is uniform
(b) The resistance over small sections of the filament decreases with time
(c) The filament emits more light at higher band of frequencies before it breaks up
(d) The filament consumes less electrical power towards the end of the life of the bulb

14. When a potential difference is applied across, the current passing through **[1999S - 3 Marks]**
(a) an insulator at 0 K is zero
(b) a semiconductor at 0 K is zero
(c) a metal at 0 K is finite
(d) a *p-n* diode at 300K is finite, if it is reverse biased

15. Capacitor C_1 of capacitance 1 micro-farad and capacitor C_2 of capacitance 2 microfarad are separately charged fully by a common battery. The two capacitors are then separately allowed to discharge through equal resistors at time $t = 0$. **[1989 - 2 Marks]**
(a) The current in each of the two discharging circuits is zero at $t = 0$.
(b) The currents in the two discharging circuits at $t = 0$ are equal but not zero.
(c) The currents in the two discharging circuits at $t = 0$ are unequal.
(d) Capacitor C_1, losses 50% of its initial charge sooner than C_2 loses 50% of its initial charge.

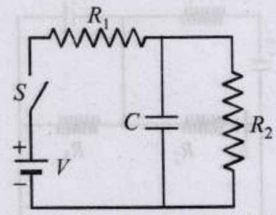
7 Match the Following

16. Column I gives some devices and Column II gives some processes on which the functioning of these devices depend. Match the devices in Column I with the processes in Column II and indicate your answer by darkening appropriate bubbles in the 4 × 4 matrix given in the ORS. **[2007]**

	Column I		Column II
(A)	Bimetallic strip	(p)	Radiation from a hot body
(B)	Steam engine	(q)	Energy conversion
(C)	Incandescent lamp	(r)	Melting
(D)	Electric fuse	(s)	Thermal expansion of solids

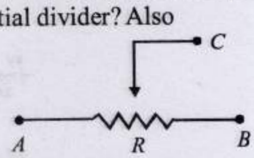
10 Subjective Problems

17. In the given circuit, the switch S is closed at time $t = 0$. The charge Q on the capacitor at any instant t is given by $Q(t) = Q(1 - e^{-\alpha t})$. Find the value of Q_0 and α in terms of given parameters as shown in the circuit. **[2005 - 4 Marks]**

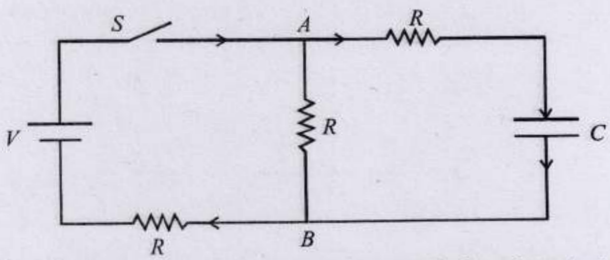


18. Draw the circuit diagram to verify Ohm's Law with the help of a main resistance of 100 Ω and two galvanometers of resistances 10^6 Ω and 10^{-3} Ω and a source of varying emf. Show the correct positions of voltmeter and ammeter. **[2004 - 4 Marks]**

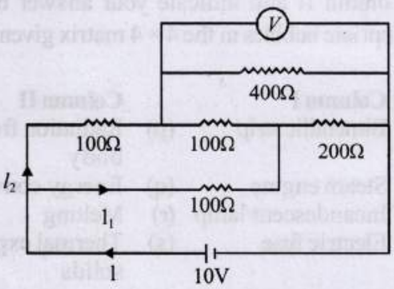
19. How a battery is to be connected so that the shown rheostat will behave like a potential divider? Also indicate the points about which output can be taken. **[2003 - 2 Marks]**



20. In the circuit shown in Figure, the battery is an ideal one, with emf V. The capacitor is initially uncharged. The switch S is closed at time $t = 0$. **[1998 - 8 Marks]**
(a) Find the charge Q on the capacitor at time t.
(b) Find the current in AB at time t. What is its limiting value as $t \to \infty$:



21. An electrical circuit is shown in Fig. Calculate the potential difference across the resistor of 400 ohm, as will be measured by the voltmeter V of resistance 400 ohm, either by applying Kirchhoff's rules or otherwise. **[1996 - 5 Marks]**

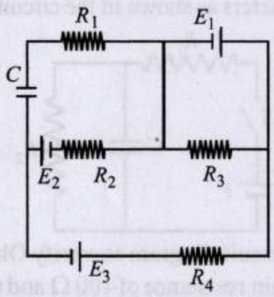


22. In the given circuit **[1988 - 5 Marks]**

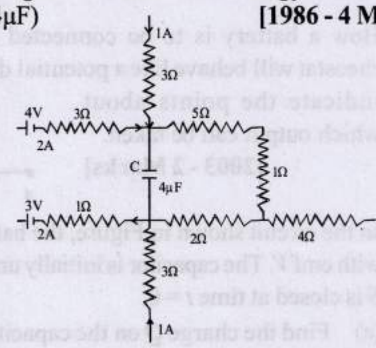
$E_1 = 3E_2 = 2E_3 = 6$ volts $\quad R_1 = 2R_4 = 6$ ohms

$R_3 = 2R_2 = 4$ ohms $\quad C = 5\,\mu f$

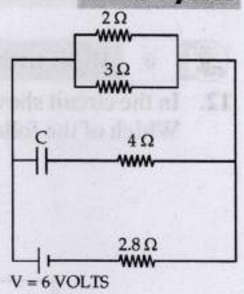
Find the current in R_3 and the energy stored in the capacitor.



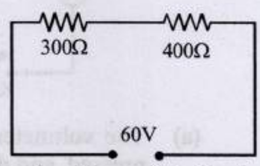
23. A part of ciucuit in a steady state along with the currents flowing in the branches, the values of resistances etc., is shown in the figure. Calculate the energy stored in the capacitor C (4μF) **[1986 - 4 Marks]**



24. Calculate the steady state current in the 2-ohm resistor shown in the circuit in the figure. The internal resistance of the battery is negligible and the capacitance of the condenser C is 0.2 microfarad. **[1982 - 5 Marks]**

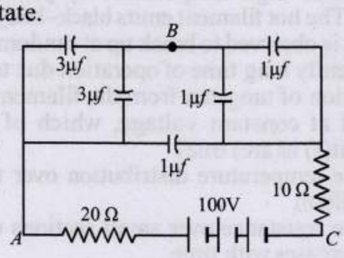


25. In the circuit shown in figure, a voltmeter reads 30 volts when it is connected across 400 ohm resistance. Calculate what the same voltmeter will read when it is connected across the 300 ohm resistance. **[1980]**



26. A battery of emf 2 volts and internal resistance 0.1 ohm is being charged with a current of 5 amps. **[1980]**
In what direction will the current flow inside the battery?
What is the potential difference between the two terminal of the battery?

27. In the diagram shown find the potential difference between the points A and B and between the points B and C in the steady state. **[1979]**



Answer Key

Topic-1 : Electric Current, Drift of Electrons, Ohm's Law, Resistance and Resistivity

1. (c) 2. (c) 3. (c) 4. (d) 5. (d) 6. (True) 7. (False) 8. (a,c,d) 9. (c)

Topic-2 : Combination of Resistances

1. (b) 2. (a) 3. (c) 4. (a) 5. (c) 6. (1) 7. (0) 8. $\left(\frac{R}{2}\right)$ 9. (a, d) 10. (d)

Topic-3 : Kirchhoff's Laws, Cells, Thermo e.m.f. & Electrolysis

1. (b) 2. (5) 3. (False) 4. (a,b,c,d) 5. (a,b,c,d) 6. (a,b,d) 7. (a,b,c,d)

Topic-4 : Heating Effect of Current

1. (d) 2. (c) 3. (a) 4. (d) 5. (c) 6. (b) 7. (4) 8. (20) 9. (c,d) 10. (b,d)

Topic-5 : Wheatstone Bridge and Defferent Measuring Instruments

1. (c) 2. (b) 3. (a) 4. (a) 5. (a) 6. (a) 7. (5) 8. (3) 9. (0.27) 10. (d)

Topic-6 : Miscellaneous (Mixed Concepts) Problems

1. (c) 2. (b) 3. (b) 4. (a) 5. (b) 6. (b) 7. (c) 8. (b) 9. (a) 10. (5)
11. (2) 12. (a, b, c, d) 13. (c, d) 14. (a,b,d) 15. (b, d) 16. A → s; B → q; C → p,q; D → q,r

Hints & Solutions

Topic-1: Electric Current, Drift of Electrons, Ohm's Law, Resistance and Resistivity

1. **(c)** Electric field at a distance r from line charge

$$E = \frac{\lambda}{2\pi\varepsilon r} = \frac{dV}{dr} \qquad (\lambda = \text{linear charge density of wire})$$

$$dV = -\frac{\lambda}{2\pi\varepsilon r}dr$$

Current through the elemental shell

$$I = \frac{|dV|}{dr} = \frac{\frac{\lambda}{2\pi\varepsilon r}dr}{\frac{1}{\sigma}\times\frac{dr}{2\pi rl}} = \frac{\lambda\sigma l}{\varepsilon}$$

$$\left(\because R = \rho\frac{l}{A} \therefore dR = \rho\frac{dr}{2\pi rl} = \frac{1}{\sigma}\frac{dr}{2\pi rl}\right)$$

This current is radially outwards,

$$\therefore \frac{d}{dt}(\lambda l) = \frac{-\lambda\sigma l}{\varepsilon} \Rightarrow \int_{\lambda_0}^{\lambda}\frac{d\lambda}{\lambda} = -\left(\frac{\sigma}{\varepsilon}\right)\int_0^t dt$$

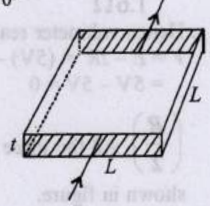
$$\Rightarrow \lambda = \lambda_0 e^{-(\sigma/\varepsilon)t}$$

$$\therefore J = \frac{I}{2\pi rl} = \frac{\lambda\sigma l}{2\pi\varepsilon rl} = \frac{\lambda\sigma}{2\pi\varepsilon r}$$

$$\text{or, } J = \left(\frac{\lambda_0\sigma}{2\pi\varepsilon r}\right)e^{-(\sigma/\varepsilon)t} \Rightarrow J = J_0 e^{-(\sigma/\varepsilon)t}$$

2. **(c)** We know resistance, $R = \rho\frac{l}{a}$

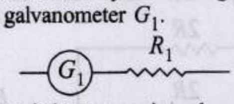
Here $l = L$ and $a = L \times t$



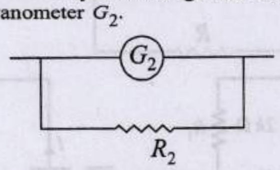
$$\therefore \quad R = \frac{\rho L}{L \times t} = \frac{\rho}{t}$$

Hence R is independent of L and inversely proportional to t.

3. **(c)** A voltmeter is made by connecting a high resistance R_1 in series with the galvanometer G_1.



An ammeter is made by connecting a low resistance R_2 in parallel with the galvanometer G_2.



Voltmeter is connected in parallel with the test resistor R_T in circuit.
Ammeter is connected in series with the test resistor R_T in circuit.
A variable voltage source V is connected in series with the test resistor R_T in circuit.

4. **(d)** Copper is a metal whereas Germanium is Semi-conductor. Resistance of metal decreases and semi-conductor increases with decrease in temperature.

5. **(d)** Resistance increases with temperature as

$R_t + R_0(1 + \alpha t)$

$R_1 = R_0(1 + \alpha t_1) \Rightarrow 1 = R_0[1 + 0.00125 \times 27]$

$R_2 = R_0(1 + \alpha t_2) \Rightarrow 2 = R_0[1 + 0.00125 \times t_2]$

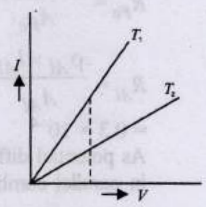
Solving we get

$T_2 = 854°C = 854°C + 273°C = 1127\ K$

6. **True,** From the given voltage, current graph

$$\text{Slope of graph} = \frac{I}{V} = \frac{1}{R}$$

$$\Rightarrow \text{Resistance, } R = \frac{1}{\text{slope of graph}}$$



$(\text{Slope})_{T_2} < (\text{Slope})_{T_1} \therefore (\text{Resistance})_{T_2} > (\text{Resistance})_{T_1}$

For a metallic wire, resistance increases with temperature, $\therefore T_2 > T_1$

7. **False,** Due to thermal energy, electrons in a conductor are free and have thermal velocities. The electrons have motion in random directions even in the absence of potential difference.

8. **(a, c, d)** Resistance of elementary strips

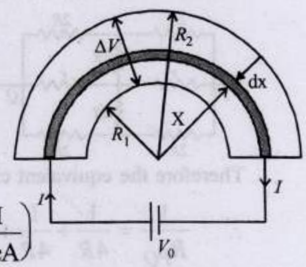
$$\int\frac{1}{d_R} = \int_{R_1}^{R_2}\frac{tdx}{\rho\pi x} \Rightarrow \frac{1}{R} = \frac{t}{\pi\rho}ln\left(\frac{R_2}{R_1}\right)$$

$$\text{Resistance, } R = \frac{\pi\rho}{t\,ln\left(\frac{R_2}{R_1}\right)} \Rightarrow I = \frac{V_0}{R} = \frac{V_0 t\, ln\left(\frac{R_2}{R_1}\right)}{\pi\rho}$$

Hence option (a) is correct.

And, for circular motion of electron, ΔV develops Inner surface at higher potential so that electric field develops radially outward.

So option (b) is correct.



$$\frac{mV_d^2}{r} = q\vec{E} \Rightarrow \vec{E} = \frac{mV_d^2}{qr}$$

$$\vec{E} = \frac{mI^2}{n^2e^2A^2qr}$$

$$\left(\because \text{Drift velocity, } V_d = \frac{I}{neA}\right)$$

$$\Delta V = \int\vec{E}.\vec{dr} \quad \text{or, } \Delta V \propto V_d^2 \quad \therefore \Delta V \propto I^2$$

Hence option (d) is correct.

9. **(c)** The conductivity (σ) of a semiconductor increases with increase in temperature i.e. the resistivity (ρ) decreases with increase in temperature as $\rho = \frac{1}{\sigma}$.

In a conducting solid, the collisions become more frequent with increase of temperature.

10. As we know, resistance, $R = \rho\frac{l}{A}$

And $V = Al \Rightarrow A = \frac{V}{l}$ (V = volume of wire)

$$\therefore R = \frac{\rho l}{V/l} = \frac{\rho l^2}{V}$$

Here ρ and V are constant $\therefore R \propto l^2$

$\therefore$ Percentage change in resistance $\frac{\Delta R}{R} \times 100 = 2$ (%change in l) = 2(0.1%) = 0.2%

Topic-2: Combination of Resistances

1. **(b)** As resistance of wire, $R = \int \rho \frac{l}{A}$

$$R_{Fe} = \frac{\rho_{Fe} \times l_{Fe}}{A_{Fe}} = \frac{10^{-7} \times 50 \times 10^{-3}}{4 \times 10^{-6}} = \frac{25}{2} \times 10^{-4}$$

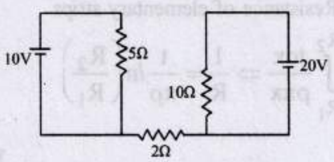
$$R_{Al} = \frac{\rho_{Al} \times l_{Al}}{A_{Al}} = \frac{2.7 \times 10^{-8} \times 50 \times 10^{-3}}{(49-4) \times 10^{-6}} = \frac{2.7 \times 50}{45} \times 10^{-5}$$

$= 0.3 \times 10^{-4}$

As potential difference across both resistors is same, so they are in parallel combination.

$$\therefore R_{PQ} = \frac{R_{Fe} \times R_{Al}}{R_{Fe} + R_{Al}} = \frac{12.5 \times 10^{-4} \times 0.3 \times 10^{-4}}{12.8 \times 10^{-4}} = \frac{1875}{64} \mu\Omega$$

2. **(a)** The current in 2Ω resistor = zero because it is not a part of any closed loop.

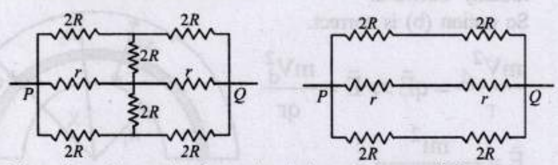


3. **(c)** Given resistance of each resistor 'R'

$$R_{PQ} = \frac{5}{11}R, R_{QR} = \frac{4}{11}R \text{ and } R_{PR} = \frac{3}{11}R$$

$\therefore R_{PQ}$ is maximum.

4. **(a)** The circuit above and below the axis POQ symmetrical and represents balanced wheatstone bridge. Hence the central resistance 2R is ineffective.



Therefore the equivalent circuit is redrawn as follows.

$$\therefore \frac{1}{R_{PQ}} = \frac{1}{4R} + \frac{1}{4R} + \frac{1}{2r} = \frac{r + r + 2R}{4Rr}$$

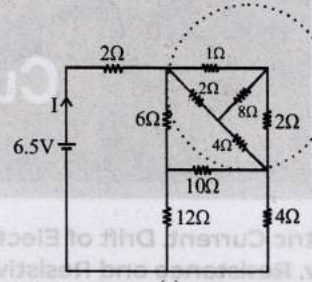
for, $R_{PQ} = \frac{2Rr}{R+r}$

5. **(c)** In the given circuit,

$$\frac{1}{R_{eq}} = \frac{1}{30} + \frac{1}{60} = \frac{90}{30 \times 60} \Rightarrow R_{eq} = 20\,\Omega$$

Current in the circuit, $I = \frac{V}{R} = \frac{2}{20} = \frac{1}{10}$A

6. **(1)** In the figure (a) no current flows through 8Ω resistance



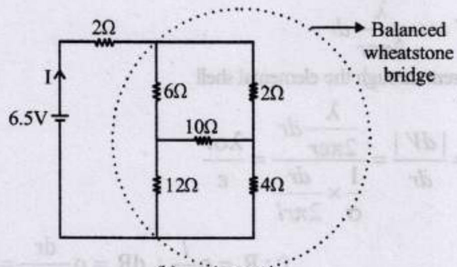
$$\frac{1}{R_{eq}} = \frac{1}{3} + \frac{1}{6}$$

$$\therefore R_{eq} = \frac{3 \times 6}{3+6} = 2\Omega$$

(a)

Again the equivalent resistance of balanced wheatstone bridge fig (b) no current through 10Ω resistance.

$$\therefore R_{eq} = \frac{6 \times 18}{24} = \frac{9}{2}\Omega$$



(b)

Therefore the current through the resistor $R = 2\Omega$

$$I = \frac{V}{R} = \frac{6.5}{2 + \frac{9}{2}} = \frac{6.5}{6.5} = 1A$$

7. **(0 V)** Here in the circuit 8 batteries each of 5V therefore, net emf of the circuit = 8 (5V) = 40 V

Internal resistance of each cell, $r = 0.2\Omega$.

Net resistance in the circuit = 8 (0.2 Ω) = 1.6 Ω

$\therefore$ Current flowing through the circuit,

$$I = \frac{40\,\text{V}}{1.6\,\Omega} = 25\,\text{A}$$

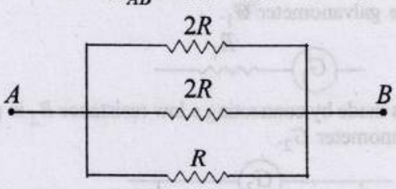
Hence voltmeter reading

$V = E - IR$ = (5V) – (25A) (0.2 Ω)

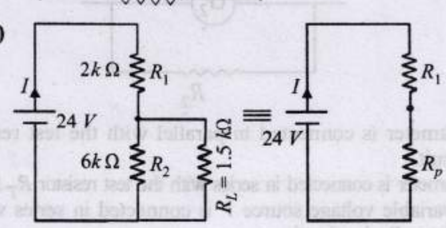
= 5V – 5V = 0

8. $\left(\frac{R}{2}\right)$ All the three resistances 2R, 2R and R are in parallel as shown in figure.

Hence, $\frac{1}{R_{AB}} = \frac{1}{2R} + \frac{1}{2R} + \frac{1}{R} = \frac{2}{R}$ or, $R_{AB} = \frac{R}{2}$



9. **(a, d)**



$R_p = \frac{R_2 \times R_L}{R_2 + R_L} = \frac{6 \times 1.5}{6 + 1.5} = \frac{9}{7.5} k\Omega$

$\therefore R_{total} = R_1 + R_p = 2 + \frac{9}{7.5} = 3.2 \; k\Omega$

(a) $I = \frac{V}{R} = \frac{24}{3.2} mA = 7.5 mA$

$I = I_{R_1}$

$I_{R_2} = \left(\frac{R_L}{R_L + R_2}\right) I = \left(\frac{1.5}{1.5 + 6}\right) \times 7.5 = 1.5 \; mA$

$\therefore I_{R_L} = I_{R_1} - I_{R_2} = 7.5 - 1.5 = 6mA$

(b) Potential difference across load

$V_{RL} = (I_{RL}) R_L = 6 \times 1.5 = 9V$

(c) Ratio of powers dissipated in R_1 and R_2

$\frac{PR_1}{PR_2} = \frac{(I_{R_1})^2 R_1}{(I_{R_2})^2 R_2} = \frac{(7.5)^2 \times 2}{(1.5)^2 \times 6} = \frac{25}{3}$

(d) When R_1 and R_2 are interchanged, then

$R_P^1 = \frac{R_2 R_L}{R_2 + R_L} = \frac{2 \times 1.5}{3.5} = \frac{6}{7} k\Omega$

$R'_{total} = 6 + R'_p = 6 + \frac{6}{7} k\Omega$

Now P.d. across R_L

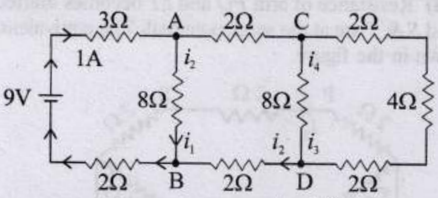
$V'_{RL} = 24\left(\frac{6/7}{6 + 67}\right) = 3V$

i.e., Now potential becomes $\frac{3}{9} = \frac{1}{3}$ rd. Therefore power dissipated $P = \frac{V^2}{R}$ or $P \propto V^2$ will decrease by a factor of 9.

10. **(d)** Here net resistance of the circuit = 9Ω.

$\therefore$ Current drawn from the battery,

$i = \frac{V}{R} = \frac{9}{9} = 1A$ = current through 3Ω resistor



Potential difference between A and B

$V_A - V_B = 9 - 1(3 + 2) = 4V = 8i_1$

$\therefore i_1 = 0.5 A \quad \therefore i_2 = 1 - i_1 = 0.5 A$

Similarly, potential difference between C and D

$V_C - V_D = (V_A - V_B) - i_2(2 + 2)$

$= 4 - 4i_2 = 4 - 4(0.5) = 2V = 8i_3$

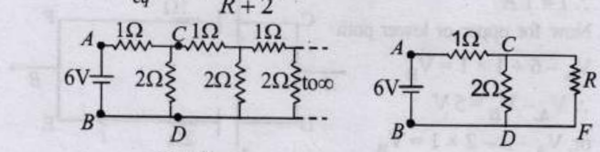
$\therefore i_3 = 0.25A \quad \therefore i_4 = i_2 - i_3 = 0.5 - 0.25 = 0.25A$

11. (i) In case of infinite ladder of resistances, the effective resistance, remains same when one identical item is added or removed from it.

Effective resistance between points C and D be R then the circuit can be redrawn as shown

Effective resistance between A and B

$R_{eq} = 1 + \frac{2 \times R}{R + 2}$.



$\therefore \quad 1 + \frac{2 \times R}{R + 2} = R$

$\Rightarrow \quad R + 2 + 2R = R^2 + 2R \Rightarrow R^2 - R - 2 = 0$

$\Rightarrow \quad R^2 - 2R + R - 2 = 0 \Rightarrow R(R - 2) + 1(R - 2) = 0$

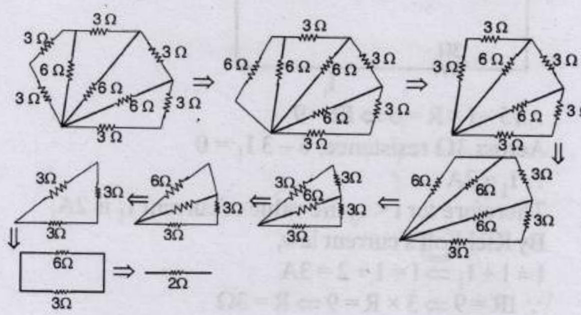
$\Rightarrow \quad [R + 1][R - 2] = 0 \Rightarrow R = 2\Omega$.

(ii) $R_{AB} = 1\Omega + 1\Omega = 2\Omega \quad \therefore I_{AB} = \frac{6}{2} = 3A$

$i_{CD} = i_{EF}$ as resistances $R_{CD} = R_{EF}$

$\therefore \quad i_{CD} = i_{EF} = \frac{3}{2} = 1.5 A$

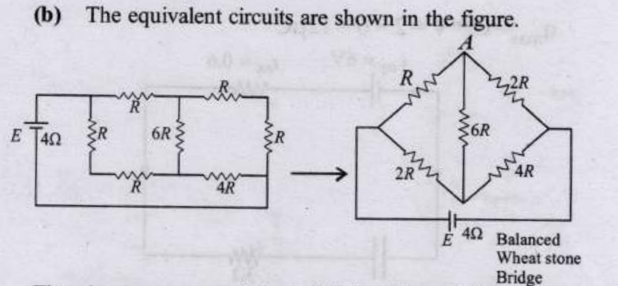
12.



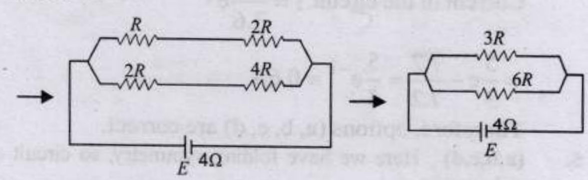
Hence resistance between A and B, $R_{AB} = 2\Omega$

Topic-3: Kirchhoff's Laws, Cells, Thermo e.m.f. & Electrolysis

1. **(b)** The equivalent circuits are shown in the figure.



The circuit represents balanced Wheatstone Bridge. Hence no current will flow across 6R Ω resistance



$\frac{1}{R_{eq}} = \frac{1}{3R} + \frac{1}{6R} \Rightarrow R_{eq} = \frac{(3R)(6R)}{(3R) + (6R)} = 2R$

For maximum power, $R_{external} = R_{internal}$

$2R = 4\,\Omega \therefore R = 2\,\Omega$

2. **(5)** Let i be the current flowing in the circuit. Applying Kirchhoff's law KVL in the loop CDEFC

$-3-2i-i+6=0 \quad \Rightarrow 3i=3$

$\therefore i=1\text{ A}$

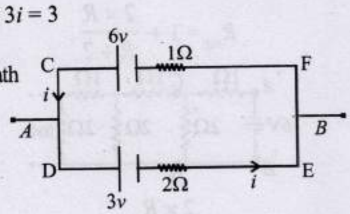
Now for upper or lower path

$V_A-6+1\times 1=V_B$

$\therefore V_A-V_B=5\text{ V}$

or, $V_A-3-2\times 1=V_B$

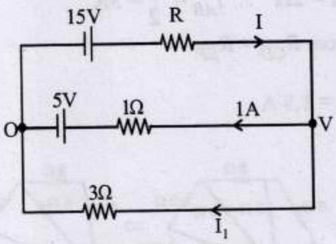
$\therefore \quad V_A-V_B=5\text{V}$



3. **False,** In an electrolytic solution, the electric current is mainly due to the movement of ions not electrons.

4. **(a, b, c, d)** From circuit diagram, voltage drop across 1Ω resistance

$V=5+1\times 1=6\text{ V}$



$\therefore 15-I\times R=6 \Rightarrow IR=9$

Across 3Ω resistance, $6-3\,I_1=0$

$\therefore I_1=2\text{A}$

Therefore for $t<t_0$ the value of current I_1 is 2A.

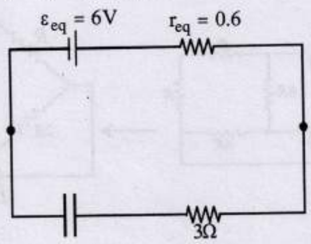
By Kichhoff's current law,

$I=1+I_1 \Rightarrow I=1+2=3\text{A}$

$\because IR=9 \Rightarrow 3\times R=9 \Rightarrow R=3\Omega$

$$E_{eq}=\frac{\frac{15}{3}+\frac{5}{1}+\frac{0}{3}}{\frac{1}{3}+\frac{1}{1}+\frac{1}{3}}=10\times\frac{3}{5}=6\text{V}$$

$q_{max}=C\times V=2\times 6=12\mu\text{C}$

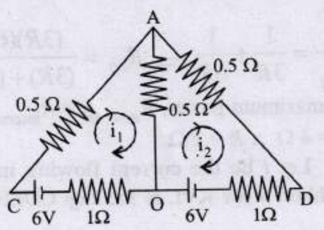


Current in the circuit $i=\frac{6}{3.6}e^{-\frac{t}{\tau}}$

$=\frac{5}{3}e^{-\frac{7.2}{7.2}}=\frac{5}{3}e^{-1}\approx 0.6\text{A}$

Therefore, options (a, b, c, d) are correct.

5. **(a,b,c,d)** Here we have folding symmetry, so circuit can be redrawn as



By mesh analysis:

In circuit ACO

$0.5i_1+0.5(i_1-i_2)+i_1-6=0$

$0.5i_1+0.5i_1-0.5i_2+i_1-6=0$

$2i_1-0.5i_2=6$

$8i_1-2i_2=24$ ....(i)

In circuit ADO

$0.5i_2+1\times i_2-12+0.5\,(i_2-i_1)=0$

$2i_2-0.5i_1=12$ ....(ii)

from (i) and (ii), we get

$7.5i_1=36$

$i_1=\frac{36}{7.5}=4.8\text{A}$

So, current through 'R_1' $=i_1=4.8$ A

Putting $i_1=4.8$A in (ii), we get

$2i_2-2.4=12$

$2i_2=14.4 \Rightarrow i_2=7.2\text{ A} \Rightarrow$ Current through $R_1=7.2$ A

So, current through $R_2=\frac{|i_2-i_1|}{2}=1.2\text{A}$

Current through $R_5=\frac{i_1}{2}=2.4\text{A}$

6. **(a, b, d)** No current is flowing through resistance R_2.

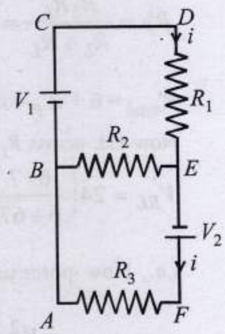
Applying KVL in loop

$V_1-iR_1+V_2-iR_3=0$

$\therefore \quad i=\frac{V_1+V_2}{R_1+R_3}$ ... (i)

Applying KVL in loop BCDEB

$v_1-iR_1=0 \;\therefore\; i=\frac{V}{R_1}$ ...(ii)



From eq. (i) & (ii) $\frac{V_1}{R_1}=\frac{V_1+V_2}{R_1+R_3}$

$\therefore \quad V_1R_1+V_1R_3=V_1R_1+V_2R_1$

$\Rightarrow \quad V_1R_3=V_2R_1$

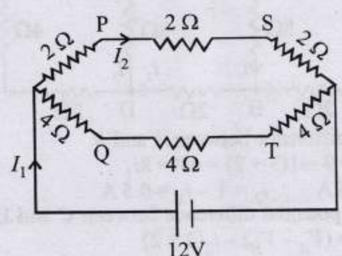
If $V_1=V_2$ then $R_1=R_3=R_2$

If $V_1=V_2$ then $R_1=R_3=2R_2$

If $V_1=2V_2$ then $2R_3=R_1$

If $2V_1=V_2$ then $R_3=2R_1=R_2$

7. **(a, b, c, d)** Resistance of arm *PQ* and *ST* becomes ineffective as *P* & *Q* and *S* & *T* are at the same potential. The equivalent circuit is as shown in the figure.



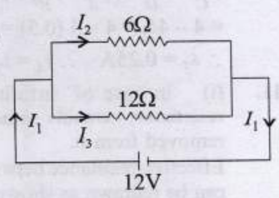
The resistance of the upper arm

$R_1=2\Omega+2\Omega+2\Omega=6\Omega$

The resistance of the lower arm

$R_2=4\Omega+4\Omega+4\Omega=12\Omega$

Equivalent resistance of the circuit,



$$R_{eq} = \frac{R_1R_2}{R_1+R_2} = \frac{(6\Omega)(12\Omega)}{6\Omega+12\Omega} = 4\Omega$$

$$\therefore I_1 = \frac{12V}{4\Omega} = 3A \quad I_2 = \left(\frac{12}{6+12}\right)\times 3 = 2A$$

$$I_3 = I_1 - I_2 = 1A$$

Potential difference across A and P,

$$V_A - V_P = I_2 \times 2\Omega = (2A)(2\Omega)$$

$$12V - V_P = 4V \text{ or } V_P = 8V$$

Potential difference across A and Q,

$$V_A - V_Q = I_3 \times 2\Omega = (1A)(4\Omega)$$

$$12V - V_Q = 4V$$

$$V_Q = 12V - 4V = 8V$$

Potential difference across P and S,

$$V_P - V_S = (2A)(2W) = 4V$$

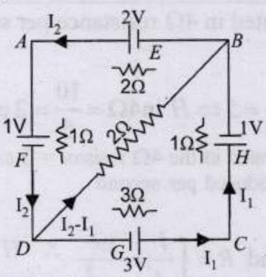
$$8V - V_S = 4V \Rightarrow V_S = 4V$$

$$\therefore V_s < V_Q$$

8. Applying Kirchhoff's voltage law KVL in loop $BDAB$

$$+2(I_2 - I_1) + 1 + 1 \times I_2 - 2 + 2I_2 = 0$$

$$\Rightarrow 2I_1 - 5I_2 = -1 \quad \text{... (i)}$$



Applying Kirchhoff's law KVL in loop $BCDB$, we get

$$-2(I_2 - I_1) + 1 + I_1 - 3 + 3I_1 = 0$$

$$\Rightarrow 3I_1 - I_2 = 1 \quad \text{... (ii)}$$

Solving eq. (i) and (ii), we get $I_1 = 6/13$ A and $I_2 = \frac{5}{13}$ A

(i) Potential difference between B and D,

$$V_B + \left[\frac{5}{13} - \frac{6}{13}\right]\times 2 = V_D \quad \therefore V_B - B_D = \frac{2}{13}\text{ V}$$

(ii) p.d. across $G = 3 - \frac{6}{13}\times 3 = \frac{39-18}{13} = \frac{21}{13}$ V

[$\because$ the cell is in discharging mode]

p.d. across $H = 1 + 1 \times \frac{6}{13} = \frac{19}{13}$ V

[$\because$ cell is in charging mode]

9. (i) Since no current is taken from the battery

$$\therefore V_{AB} = E_{eq} = \frac{\Sigma E/r}{\Sigma \frac{1}{r}} = \frac{\frac{E_1}{r_1}+\frac{E_2}{r_2}+\frac{E_3}{r_3}}{\frac{1}{r_1}+\frac{1}{r_2}+\frac{1}{r_3}}$$

$$= \frac{\left(3/1 + 2/1 + 1/1\right)}{\left(1/1\right)+\left(1/1\right)+\left(1/1\right)} = 2V$$

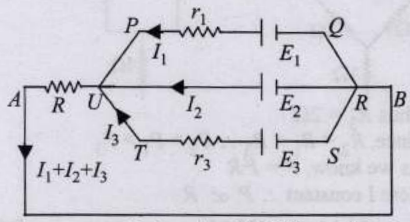
Internal resistance of equivalent battery = $\frac{1}{3}\Omega$

$$i_1 = \frac{V_B - V_A + E_1}{r_1} = \frac{-2+3}{1} = 1A$$

$$i_2 = \frac{V_B - V_A + E_2}{r_2} = \frac{-2+2}{1} = 0$$

$$\text{and } i_3 = \frac{V_B - V_A + E_3}{r_3} = \frac{-2+1}{1} = -1A$$

(ii) If r_2 is short-circuited then resistance of this branch in zero.



Applying Kirchhoff's law in $PQRUP$ starting from P moving clockwise

$I_1r_1 - E_1 + E_2 = 0$ or $I_1 - 3 + 2 = 0 \quad \therefore I_1 = 1$A

Applying Kirchhoff's law in $URSTU$ starting from U moving clockwise

$-E_2 + E_3 - I_3r_3 = 0$ or $-2 + 1 - I_3 = 0 \quad \therefore I_3 = -1$A

Here – ve sign of I_3 indicates that the direction of current in branch $UTSR$ is opposite to that assumed.

Applying Kirchhoff's law in $AURBA$ starting from A moving clockwise.

$(I_1 + I_2 + I_3)R - E_2 = 0$ or $(1 + I_2 - 1)R = 2 \therefore I_2 = 2$A

Hence, current through R, $= I_1 + I_2 + I_3 = 2$A

Topic-4: Heating Effect of Current

1. (d) We know power $P = \frac{V^2}{R}$

$\therefore$ For a constant V at a particular temperature $P \propto \frac{1}{R}$

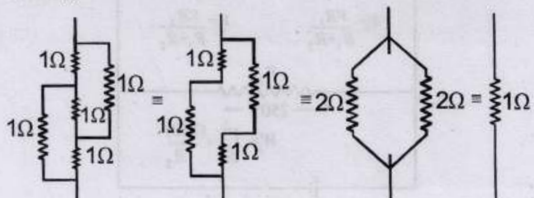
It is given that the power of the bulbs are in the order 100W > 60 W > 40W

$$\therefore \quad \frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$$

2. (c) We know power, $P = \frac{V^2}{R}$

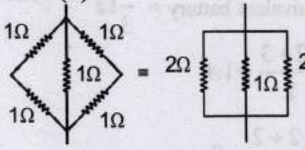
And V is constant in all three cases $\therefore P \propto \frac{1}{R}$

Case (i)



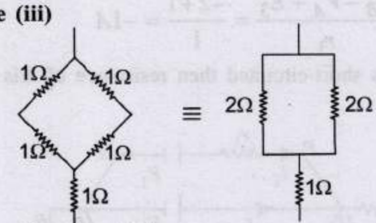
This is a case of balanced Wheatstone bridge $R_1 = 1\Omega$

Case (ii)



$$\frac{1}{R^2}=\frac{1}{2}+\frac{1}{1}+\frac{1}{2}\Rightarrow R_2=\frac{2}{4}=\frac{1}{2}\Omega$$

Case (iii)

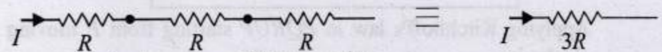


Thus $R_3 = 2\Omega$

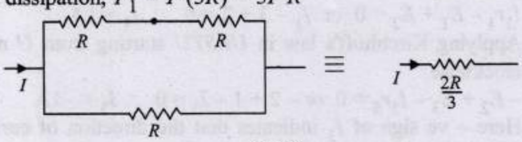
Since, $R_2 < R_1 < R_3 \therefore P_2 > P_1 > P_3$

3. **(a)** As we know, $P = I^2R$

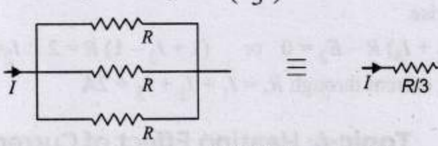
Here I constant $\therefore P \propto R$



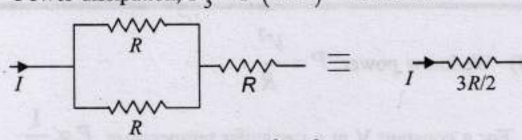
Power dissipation, $P_1 = I^2(3R) = 3I^2R$



Power dissipation, $P_2 = I^2\left(\frac{2R}{3}\right) = 0.67I^2R$



Power dissipation, $P_3 = I^2(R/3) = 0.33I^2R$

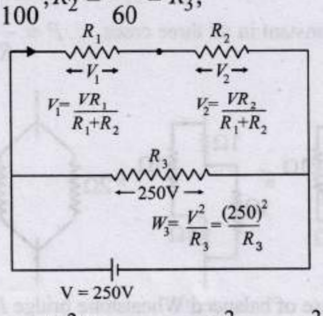


Power dissipation, $P_4 = I^2\left(\frac{3}{2}R\right) = 1.5\, I^2R$

$\therefore$ III < II < IV < I

4. **(d)** As we know, $P = \frac{V^2}{R} \therefore R = \frac{V^2}{P}$

$$\therefore \quad R_1 = \frac{V^2}{100}, R_2 = \frac{V^2}{60} = R_3;$$



$$W_1 = \frac{V_1^2}{R_1} = \frac{V^2R_1}{(R_1+R_2)^2}, W_2 = \frac{V_2^2}{R_2} = \frac{V^2R_2}{(R_1+R_2)^2}$$

and $W_3 = \frac{V^2}{R_3}$

$$W_3 : W_2 : W_1 = \frac{(250)^2}{R_3} : \frac{(250)^2R_2}{(R_1+R_2)^2} R_2 : \frac{(250)^2}{(R_1+R_2)^2} R_1$$

or $\quad W_3 : W_2 : W_1$

$$= \frac{(250)^2}{V^2}\times 60 : \frac{(250)^2}{\left[\frac{1}{100}+\frac{1}{60}\right]^2 V^4}\times\frac{V^2}{60} : \frac{(250)^2V^2}{\left[\frac{1}{100}+\frac{1}{60}\right]^2 V^4\times 1000}$$

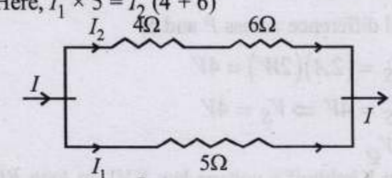
or $\quad W_3 : W_2 : W_1$

$$= 60 : \frac{100\times100\times60\times60}{160\times160\times60} : \frac{100\times100\times60\times60}{160\times160\times100}$$

$= 64 : 25 : 15$

Therefore $W_1 < W_2 < W_3$

5. **(c)** Here, $I_1 \times 5 = I_2(4+6)$



$$\therefore I_1 = 2I_2 \Rightarrow I_2 = \frac{I_1}{2}$$

$$\frac{\text{Heat generated in 5}\Omega\text{ resistance per second}}{\text{Heat generated in 4}\Omega\text{ resistance per second}} = \frac{I_1^2\times5}{\frac{I_1^2\times4}{4}}$$

$$\Rightarrow \frac{10}{H \text{ in } 4\Omega} = 5 \Rightarrow H \text{ in} 4\Omega = \frac{10}{5} = 2 \text{ cal/s}$$

$\therefore$ Heat generated in the 4Ω resistor = 2 calories/s

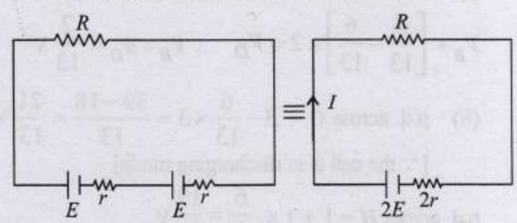
6. **(b)** Heat produced per second

$$H = \frac{V^2}{R} \text{ and } R = \int\frac{l}{A} = \frac{\rho\ell}{\pi r^2} \quad \therefore \quad H = V^2\left(\frac{\pi r^2}{\rho\ell}\right)$$

or $\quad H = \left(\frac{\pi V^2}{\rho}\right)\frac{r^2}{\ell}$ or, $H \propto \frac{r^2}{l}$

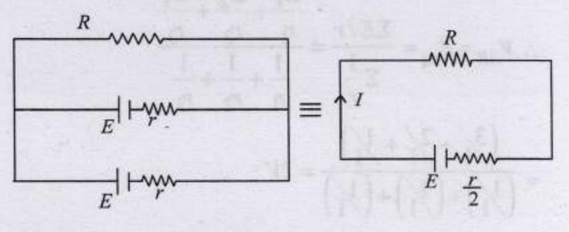
Thus heat developed (H) is doubled if both length (ℓ) and radius (r) are doubled.

7. **(4)** **Cells connected in series**



$$J_1 = I^2R = \left(\frac{2E}{2r+R}\right)^2 .R$$

Cells connected in parallel



$J_2 = I^2R = \left(\frac{E}{R+\frac{r}{2}}\right)^2 \times R$

$\therefore J_1 = 2.25\,J_2$ (Given)

$\frac{(2E)^2}{(2r+R)^2}.R = 2.25\frac{E^2}{(R+\frac{r}{2})^2}.R$

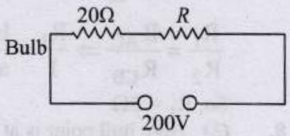
$\Rightarrow \frac{4}{(2r+R)^2} = \frac{2.25}{\left(R+\frac{r}{2}\right)^2}$

$\Rightarrow 4[R+0.5]^2 = 2.25[2+R]^2 \quad [\because r = 1\Omega]$

$\Rightarrow 2\,(R+0.5) = 1.5\,(2+R) \therefore R = 4\Omega$

8. **(20)** We know,

Power $P = \frac{V^2}{R}$



$\therefore \quad R_{bulb} = \frac{V^2}{P} = \frac{100\times100}{500} = 20\Omega$

This would be possible only when $R = 20\ \Omega$ is in series with the bulb resistance ($R_{bulb} = 20\Omega$) because in that case both resistances will share equal p.d of 100V each.

9. **(c, d)** When both switches are open

$R_{eq1} = \frac{16}{11}\Omega, R_{eq2} = \frac{6}{11}\Omega$

So, $R_{eq1} > R_{eq2}$

For voltage source, $P = \frac{V^2}{R_{eq}} \Rightarrow P \propto \frac{1}{R_{eq}}$

$\Rightarrow P_1 < P_2 \Rightarrow$ (a) is correct.

For constant current source, $P = i^2 R_{eq}$

$\Rightarrow \quad P \propto R_{eq}$

$\Rightarrow \quad P_1 > P_2 \Rightarrow$ (b) is correct.

When switch is closed

$R'_{eq1} = \frac{5}{11}\Omega, R'_{eq2} = \frac{1}{2}\Omega$

So, $R'_{eq1} < R_{eq1}$

For voltage source

$P = \frac{V^2}{R} \Rightarrow P \propto \frac{1}{R} \Rightarrow Q_1 > P_1 \Rightarrow$ (c) is correct

For current source

$P = i^2 R \Rightarrow P \propto R \Rightarrow Q_1 < Q_2 \Rightarrow$ (d) is incorrect.

10. **(b, d)** Heat produced, $H = \left(\frac{V^2}{R}\right)t = \frac{V^2}{R}\times 4$ ...(i)

where $R = \rho\frac{l}{A} = \frac{4\rho l}{\pi d^2}$

When resistances are connected in series

Total resistance $= R_1 + R_2 = 2\left[\frac{4\rho l}{4\pi d^2}\right] = 2\times\frac{R}{4} = \frac{R}{2}$

$\therefore H = \frac{V^2}{R/2}\times t_2$ ...(ii)

From eq. (i) and (ii) $t_2 = 2$ min.

When resistance are connected in parallel

Total resistance $= \frac{R_1R_2}{R_1+R_2} = \frac{R_1^2}{2R_1} = \frac{R/4}{2} = \frac{R}{8}$

$\therefore H = \frac{V^2}{R/8}\times t_2$ ...(iii)

From eq. (i) and (iii) $t_2 = 0.5$ min

11. Resistance of the heater coil, $R = \frac{V^2}{P} = \frac{100\times100}{100} = 10\ \Omega$

Voltage across the coil of heater if it operates with a power $P' = 62.5$ W

$V' = \sqrt{R\times P'} = \sqrt{10\times62.5} = \sqrt{625} = 25$

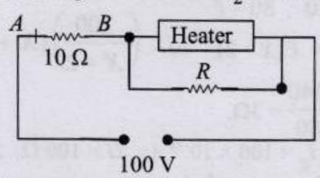
Since the voltage drop across the heater is $25V$ hence voltage drop across 10Ω resistor is $(100-25) = 75V$.

$\therefore$ Current in the circuit, $= I = \frac{V}{R} = \frac{75}{10} = 7.5\,A$

This current divides into two parts. Let I_1 be the current that passes through the heater.

$\therefore V' = I_1 R \Rightarrow 25 = I_1 \times 10 \therefore I_1 = 2.5\,A$

Thus current through resistance 'R' $I_2 = 7.5 - 2.5 = 5$A.



From Ohm's law resistance across resistor R,

$V' = I_2 \times R \Rightarrow 25 = 5\times R \quad \therefore R = 5\Omega$

Topic-5: Wheatstone Bridge and Different Measuring Instruments

1. **(c)** In case of balanced meter bridge

$\frac{R}{l} = \frac{X}{100-l}$ Given: $X = 90\ \Omega$, $l = 40.0$ cm

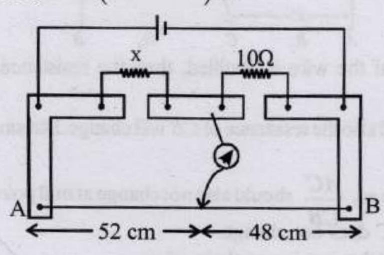
$\therefore R = \frac{Xl}{100-l} = \frac{90\times40}{60} = 60\Omega$

$\therefore \frac{\Delta R}{R} = \frac{\Delta l}{l} + \frac{\Delta(100-l)}{100-l} \Rightarrow \frac{\Delta R}{60} = \frac{0.1}{40} + \frac{0.1}{60}$

$\therefore \Delta R = 0.25\Omega$

Therefore, $R = (60 \pm 0.25)\Omega$

2. **(b)**



Applying balanced wheatstone bridge condition $\frac{P}{Q} = \frac{R}{S}$

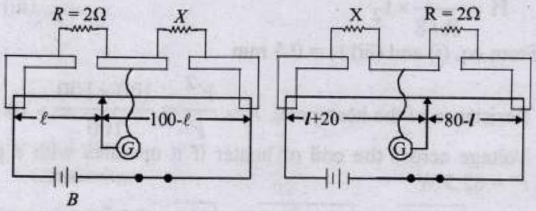
$\frac{X}{\ell_1} = \frac{10}{\ell_2}$

Here $\ell_1 = 52 +$ end correction $= 52 + 1 = 53$ cm

$\ell_2 = 48 +$ end correction $= 48 + 2 = 50$ cm or $\frac{X}{53}=\frac{10}{50}$ $\therefore$ $X=\frac{53}{5}=10.6\Omega$

3. **(a)** When the bridge is balanced $x > 2\Omega$

Applying balanced wheatstone bridge condition, $\frac{P}{Q}=\frac{R}{S}$



$$\frac{R}{\ell}=\frac{X}{100-\ell}$$

or, $100R-R\ell=\ell X$ or, $200-2\ell=\ell X$ or, $\ell=\frac{200}{X+2}$

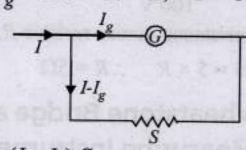
When the resistances are interchanged the jockey shifts 20 cm.

$$\therefore \quad \frac{X}{\ell+20}=\frac{2}{80-\ell} \Rightarrow 80X-\ell X=2\ell+40$$

or, $80X=\ell(X+2)+40=\left(\frac{200}{X+2}\right)(X+2)+40$

or, $X=\frac{240}{80}=3\Omega.$

4. **(a)** Here, $I_g=100\times10^{-6}A;\ \ G=100\ \Omega;\ S=0.1\ \Omega$



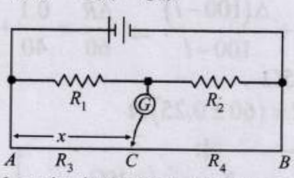
Using $I_gG=(I-I_g)S$

$$I=I_g\left(\frac{G}{S}+1\right)=100\times10^{-6}\left(\frac{100}{0.1}+1\right)$$

or, $I=100\times10^{-6}\times1000.1=100.01$ mA

5. **(a)** In case of meter bridge at null point

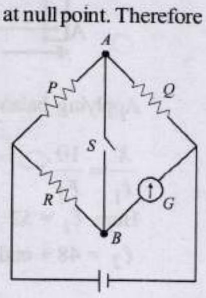
$$\frac{R_1}{R_2}=\frac{R_3}{R_4}=\frac{AC}{CB}=\frac{AC}{100-CB}$$



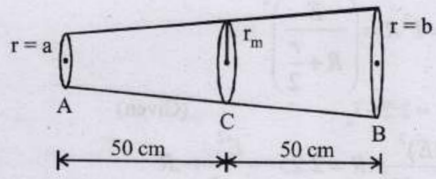
If radius of the wire is doubled, then the resistance of AC will change and also the resistance of CB will change. But since $\frac{R_1}{R_2}$ does not change so, $\frac{AC}{CB}$ should also not change at null point. Therefore the point C does not change.

6. **(a)** Since the opening or closing the switch 's' does not change the reading of galvanometer it means that in both the cases there is no current passing through S. It is the case of balanced wheatstone bridge. Thus potential at A is equal to potential at B.

$\therefore I_P=I_Q$ and $I_R=I_G$



7. **(5)**



For a frustum, $R=\frac{\rho\ell}{\pi ab}$ and $r_m=\frac{a+b}{2}$

So, $R_{AC}=\frac{\rho\ell_{/2}}{\pi(ar_m)}$

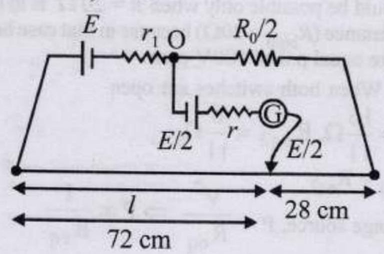
$R_{CB}=\frac{\rho\ell_{/2}}{\pi\, r_m b}$. By wheatstone bridge principal

$$\frac{R_1}{R_2}=\frac{R_{AC}}{R_{CB}}\Rightarrow\frac{R_1}{1}=\frac{b}{a}=\frac{1}{0.2}=5$$

So, $R_1=5\Omega$

8. **(3)** Here null point is at 72 cm

$$i\left(\frac{R_0}{2}+0.28R_0\right)=\frac{E_0}{2}$$



$$\Rightarrow \quad i\times0.78R_0=\frac{E_0}{2}$$

$$i=\frac{E_0}{2\times0.78R_0}=\frac{E_0}{r_1+\frac{3}{2}R_0}$$

or, $r_1+1.5\,R_0=1.56\,R_0$

$\Rightarrow$ $r_1=1.56\,R_0-1.5\,R_0=0.06\,R_0$

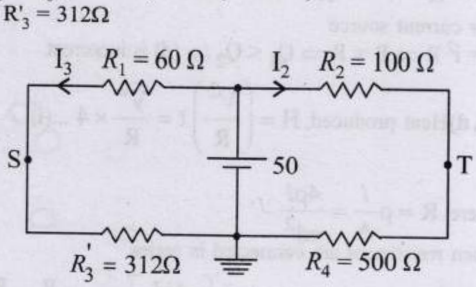
$\therefore$ $r_1=0.06\times50=3\,\Omega$

9. **(0.27)** According to question, resistance R_3 has temperature coefficient, $\alpha=0.0004°C^{-1}$

And temperature is increased by 100° C i.e., $\Delta T=100°$ C

$R'_3=R_0(1+\alpha\Delta T)=300(1+\alpha\Delta T)$

$\therefore R'_3=312\Omega$



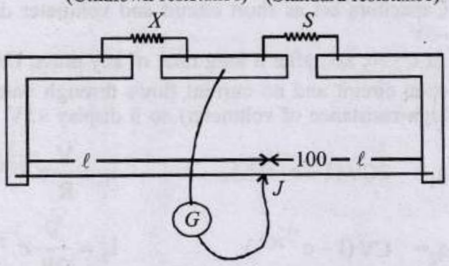
Here, $I_1=\frac{V}{R_1+R_3}=\frac{50}{372}$ and $I_2=\frac{V}{R_2+R_4}=\frac{50}{600}$

$V_S-V_T=312I_1-500I_2$

$= 312 \times \frac{50}{372} - 50 \times \frac{500}{600} = 41.94 - 41.67 = 0.27V$

Hence voltage developed between S and T = 0.27 Volt

10. **(d)** When the temperature of metal increases; its resistance increases, $R_t = R_0(1 + \propto t)$



For a meter bridge at null point or at balanced condition

$\frac{X}{\ell} = \frac{S}{100 - \ell}$ or $\frac{X}{S} = \frac{l}{100 - l}$

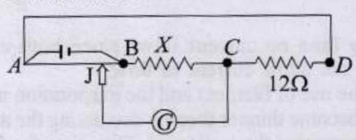
For null point 'J' at same point or, $\frac{\ell_1}{100 - \ell_1}$ to remain unchanged, $\frac{X}{S}$ should also remain unchanged. Hence if X is increasing then standard resistance 's' should also increase.

11. Position-B of null point gives most accurate reading. Null point at B is almost at the centre of resistance wire wheatstone bridge is most accurate when all the four resistances of the four arms are of the same order of magnitude.

In case of balanced wheatstone bridge condition, $\frac{P}{Q} = \frac{X}{R}$.

12. (a) No. There are no positive and negative terminals on the galvanometer. Whenever there is no current, the pointer of the galvanometer is at zero.

(b)



(c) ∵ Bridge is balanced $\frac{R_{AJ}}{R_{JB}} = \frac{0.6\rho}{0.4\rho} = \frac{12\Omega}{X}$ $\therefore X = 8\ \Omega$

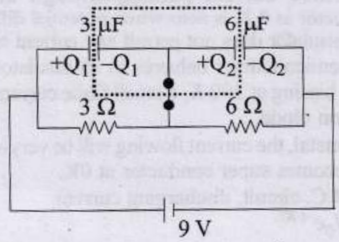
where ρ is the resistance per unit length.

Topic-6: Miscellaneous (Mixed Concepts) Problems

1. **(c)** When the switch S is open, total charge $Q_1 + Q_2 = 0$

$CV_1 + C_2V_2 = 0\ 3 \times 6 + (-6 \times 3) = 0$. When the switch is closed and steady state is reached, the current I coming from the battery is

$9 = I(3 + 6) \Rightarrow I = 1A \quad (\because V = IR)$



∴ Potential difference across 3Ω resistance = 3V

Potential difference across 6Ω resistance = 6V

∴ p.d. across 3 µF capacitor = 3V

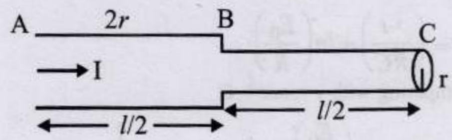
and p.d. across 6 µF capacitor = 6V

∴ Charge on 3 µF capacitor $Q_1 = 3 \times 3 = 9\ \mu C$

Charge on 6 µF capacitor $Q_2 = 6 \times 6 = 36\ \mu C$

∴ Charge flows from y to $x = 36 - 9 = 27\ \mu C$

2. **(b)** As both wire of same material ∴ $I_{AB} = I_{BC}$



(a) $\frac{V_{AB}}{V_{BC}} = \frac{I_{AB}R_{AB}}{I_{BC}R_{BC}} = \frac{R_{AB}}{R_{BC}} = \frac{\rho\frac{\ell}{2[\pi \times 4r^2]}}{\rho\frac{\ell}{2[\pi r^2]}} = \frac{1}{4}$

$\therefore V_{AB} = \frac{V_{BC}}{4}$

(b) $\frac{P_{BC}}{P_{AB}} = \frac{I^2R_{BC}}{I^2R_{AB}} = \frac{\rho\frac{\ell}{2[\pi \times 4r^2]}}{\rho\frac{\ell}{2[\pi r^2]}} = \frac{1}{4}$

∴ $P_{AB} = 4P_{BC}$,

(c) $\frac{J_{AB}}{J_{BC}} = \frac{\frac{I}{\pi \times 4r^2}}{\frac{I}{\pi \times r^2}} = \frac{1}{4}$; $\therefore J_{BC} = 4J_{AB}$

(d) $\frac{E_{AB}}{E_{BC}} = \frac{\left[\frac{V_{AB}}{\ell/2}\right]}{\left[\frac{V_{BC}}{\ell/2}\right]} = \frac{1}{4}$; $\therefore E_{BC} = 4E_{AB}$

3. **(b)** Here, change in internal energy = heat supplied

i.e., $\Delta U = Q = I^2Rt$

$= 1 \times 1 \times 100 \times 5 \times 60 = 30{,}000\ J = 30\ kJ$

4. **(a)** At any instant of time t during charging process, the transient current in the circuit

$I = \frac{V_0}{R}e^{-t/RC}$ ∴ Potential difference across resistor R

$V_R = \left[\frac{V_0}{R}e^{-t/RC}\right] \times R$

$= V_0e^{-t/RC}$ ...(i)

∴ Potential difference across C

$V_c = V_0 - V_0e^{-t/RC} = V_0(1 - e^{-t/RC})$ ...(ii)

∵ $V_c = 3V_R$

∴ $V_0\left(1 - e^{-t/RC}\right) = 3V_0.e^{-t/RC}$

⇒ $1 - e^{-t/RC} = 3e^{-t/RC}$ ⇒ $1 = 4e^{-t/RC}$

Taking log on both sides

$\log_e 1 = 2\log_e 2 + \left(-\frac{t}{RC}\right)$

$\Rightarrow \quad 0 = 2 \times 2.303 \log_{10} 2 - \dfrac{t}{RC}$

$\Rightarrow \quad t = [2 \times 2.303 \log_{10} 2] \times 2.5 \times 10^6 \times 4 \times 10^{-6}$ or, $t = 13.86$ s

5. **(b)** Current in RC circuit, $I = I_0 e^{-t/RC}$

or $\quad lnI = lnI_0 - \dfrac{t}{RC}$ or $lnI = \left(\dfrac{-t}{RC}\right) + lnI_0$

$lnI = \left(\dfrac{-t}{RC}\right) + ln\left(\dfrac{E_0}{R}\right)$

Comparing with $y = mx + C$

Intercept $= ln\left(\dfrac{E_0}{R}\right)$ and slope $= -\dfrac{1}{RC}$

So, when x is changed to $2x$ then slope increases and current becomes less. Hence new graph is Q.

6. **(b)** Post office box is also works on the principle of balanced wheatstone bridge use to measure unknown resistance. Total external resistance will be the total resistance of whole length of box. It should be connected between A and D.

7. **(c)** As the current I is independent of R_6, it follows that the resistance R_1, R_2, R_3, R_4 and R_6 must form the balanced Wheatstone bridge.∴ $R_1 R_4 = R_2 R_3$

8. **(b)** Let R be the resistance of wire.

Energy released in t second, $H = \dfrac{(3V)^2}{R} \times t \left(\because H = \dfrac{V^2}{R} t\right)$

Also, $H = mc\Delta T = \dfrac{9V^2}{R} \times t \quad (\because \ H = mc\Delta T)$ .... (i)

Let R' be the resistance of the wire of double length '$2l$'

∴ Now energy released in t-seconds

$$H' = \frac{(NV)^2}{2R} \times t \ (\because R \propto l)$$

Also $H' = m'c\Delta T = (2m)\, C\Delta T$

$2\,mc\Delta T = \dfrac{N^2V^2}{2R} \times t$ .... (ii)

Dividing eq. (i) by (ii)

$\dfrac{mc\Delta T}{2mc\Delta T} = \dfrac{9V^2 \times t / R}{N^2V^2\, t / 2R}$ or, $\dfrac{1}{2} = \dfrac{9 \times 2}{N^2}$

or, $N^2 = 18 \times 2 \quad \therefore \ N = 6$

9. **(a)** Intensity of light, $I \propto \dfrac{1}{r^2}; V \propto \dfrac{1}{r}; V \propto r^0$

10. **(5)** From $\left(\dfrac{I - I_g}{I_g}\right) S = \dfrac{V}{I_g} - R$

$\dfrac{1.5 - 0.006}{0.006} \times \dfrac{2n}{249} = \dfrac{30}{0.006} - 4990 \ \therefore \ n = \dfrac{2490}{498} = 5$

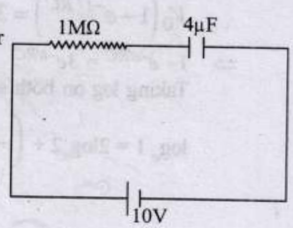
11. **(2)** The equivalent circuit of the given circuit is as shown below.

$R = 1\text{M}\Omega$, $C = 4\mu\text{F}$

∴ The time constant

$\tau = RC = 4$ sec

Potential across 4μF capacitor at any time 't'



$V = V_0\left[1 - e^{\frac{-t}{\tau}}\right]$

$\Rightarrow 4 = 10\left[1 - e^{-\frac{t}{4}}\right]$

$\Rightarrow t = 2\text{ s} \Rightarrow e^{-t/4} = 0.6 = \dfrac{3}{5}$

Taking log on both sides,

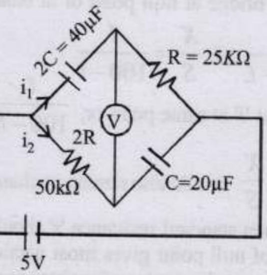
$-\dfrac{t}{4} = \ell n3 - \ell n5 \quad \Rightarrow t = 4(\ell n5 - \ell n3) = 2.5$

12. **(a, b, c, d)** At t = 0, i.e., As soon as the key is pressed, Capacitors act as short circuit and voltmeter display reading, –5V

At t = ∞, i.e., after a long time of key press, Capacitor acts as open circuit and no current flows through voltmeter (∵ very high resistance of voltmeter) so it display +5V.

$q_1 = 2CV\left(1 - e^{-t/2CR}\right)$, $\quad i_1 = \dfrac{V}{R} e^{-\frac{t}{2CR}}$

$q_2 = CV\left(1 - e^{-t/2CR}\right)$, $\quad i_2 = \dfrac{V}{2R} e^{-\frac{t}{2CR}}$



$\therefore \ \Delta V = -i_2 \times 2R + \dfrac{CV_1}{2C} = V\left[1 - 2e^{-t/2CR}\right] = 0$

i.e., At time t = ln 2s voltmeter will display reading 0 V.

At τ = 1sec, $i = \dfrac{i_0}{e}$ $\quad \left[\because i = i_0\, e^{-t/\tau}\right]$

i.e., After 1s current in the ammeter becomes $\dfrac{1}{e}$ of the initial value.

After a long time no current flows since both capacitor and voltmeter do not allow current to flow.

13. **(c, d)** With the use of filament and the evaporation involved, the filament will become thinner thereby decreasing the area of cross-section and increasing the resistance. Therefore the filament will consume less power towards the end of life.

As power, $P = \dfrac{V^2}{R}$ or, $P \propto \dfrac{1}{R} (\because V = \text{constant})$

As the evaporation is non-uniform, the area of cross-section will be different at different cross-section. Therefore temperature distribution will be non-uniform. The filament will break at the point where the temperature is maximum.

When the filament temperature is higher $\left(\lambda_n \propto \dfrac{1}{T}\right)$, it emits light of lower wavelength or higher band of frequencies.

14. **(a,b,d)** Since current passing-through an insulator and semiconductor at 0 K is zero when potential difference is applied at 0K an insulator does not permit any current to flow through it. At 0K a semiconductor behaves as an insulator.

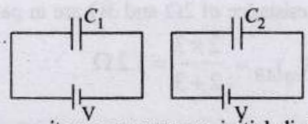
In reverse biasing at 300 K, a small finite current flows through a p-n junction diode.

In case of metal, the current flowing will be very-very high because a metal becomes super conductor at 0K.

15. **(b, d)** In R.C. circuit, discharging current

$I = I_0 e^{-t/RC}$

Initial current $I_0 = \frac{V}{R}$



As V and R for both capacitors are same so, initial discharging current will be same but non-zero.

Also, $q = q_0 e^{-t/RC}$

When $q = \frac{q_0}{2}$ then $\frac{q_0}{2} = q_0 e^{-t/RC}$

or $e^{+t/RC} = 2. \Rightarrow t = RC \log_e 2 \therefore t \propto C.$

$\therefore \frac{t_1}{t_2} = \frac{C_1}{C_2} = \frac{1}{2} = 0.5$ or, $t_1 = 0.5\, t_2$

Hence capacitor C_1 losses 50% of its initial charge sooner than C_2 losses 50% of its initial charge.

16. **A → s**

Bimetallic strip is based on thermal expansion of solids i.e., $l = l_0(1 + \alpha t)$

B → q

Steam engine is based on energy conversion.

C → p, q

Incandescent lamp is based on energy conversion i.e., electrical energy into light energy and radiation from a hot body.

D → q, r

Electric fuse is based on melting of the fuse material which in turn depends on the heating effect of current.

17. Given $Q = Q_0[1 - e^{-\alpha t}]$

Here Q_0 = maximum charge and

$$\alpha = \frac{1}{\tau_c} = \frac{1}{C_{Req}}$$

Now the maximum charge

$Q_0 = C[V_0]$ where V_0 = max potential difference across C

$$= C\left[\frac{V}{R_1 + R_2} \times R_2\right]$$

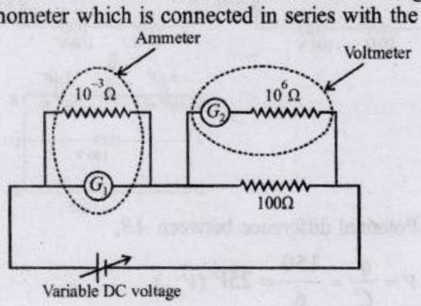
Here $\left(\frac{V}{R_1 + R_2}\right)$ is the steady state current through R_2.

And $\tau_c = C\,R_{eq} = C\left[\frac{R_1 R_2}{R_1 + R_2}\right]$

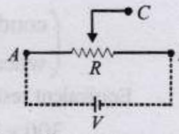
($\because R_1$ and R_2 are in parallel combination)

$$\therefore \alpha = \frac{1}{\tau_c} = \frac{R_1 + R_2}{C R_1 R_2}$$

18. To verify ohm's law, the circuit diagram is as shown below. An ammeter is a low resistance galvanometer which is connected on parallel with the resistance and voltmeter is a high resistance galvanometer which is connected in series with the resistance.

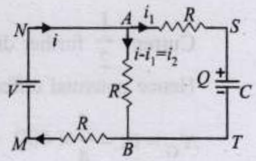


19. For rheostat to behave like a potential divider, battery should be connected across A and B. Output can be taken across the terminals A and C or B and C.



20. According to question, capacitor is initially uncharged and the switch s is closed at times $t = 0$

Let at any time t charge on capacitor C be Q. Let currents are as shown in fig. Since charge Q will increase with time 't'



$$\therefore i_1 = \frac{dQ}{dt}$$

(a) Applying KVL in the loop $MNABM$

$V = (i - i_1)R + iR$

or $V = 2iR - i_1 R$ ... (i)

Similarly, applying KVL in loop $MNSTM$,

$$V = i_1 R + \frac{Q}{C} + iR \quad \text{...(ii)}$$

Eliminating i from equation (i) and (ii), we get

$$V = 3i_1 R + \frac{2Q}{C} \quad \text{or} \quad 3i_1 R = V - \frac{2Q}{C}$$

$$\text{or} \quad i_1 = \frac{1}{3R}\left(V - \frac{2Q}{C}\right) \quad \text{or} \quad \frac{dQ}{dt} = \frac{1}{3R}\left(V - \frac{2Q}{C}\right)$$

$$\text{or} \quad \frac{dQ}{\left(V - \frac{2Q}{C}\right)} = \frac{dt}{3R} \quad \text{or} \quad \int_0^Q \frac{dQ}{\left(V - \frac{2Q}{C}\right)} = \int_0^t \frac{dt}{3R}$$

$$\text{or, } Q = \frac{CV}{2}(1 - e^{-2t/3RC})$$

$$\text{(b)} \quad i_1 = \frac{dQ}{dt} = \frac{d}{dt}\left[\frac{CV}{2}\left(1 - e^{-2t/3RC}\right)\right]$$

$$= \frac{CV}{2} \times \frac{2}{3RC} \times e^{-2t/3RC} = \frac{V}{3R} e^{-2t/3RC}$$

From equation (i)

$$i = \frac{V + i_1 R}{2R} = \frac{V + \frac{V}{3}e^{-2t/3RC}}{2R} \quad \therefore \text{Current through } AB$$

$$i_2 = i - i_1 = \frac{V + \frac{V}{3}e^{-2t/3RC}}{2R} - \frac{V}{R}e^{-2t/3RC}$$

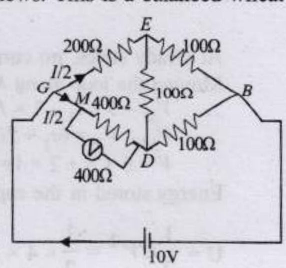
$$\Rightarrow i_2 = \frac{V}{2R} - \frac{V}{6R}e^{-2t/3RC} \quad \text{or, } i_2 = \frac{V}{2R} \text{ as } t \to \infty$$

21. We can redraw the circuit as follows. This is a balanced wheat stone bridge.

Equivalent resistance between G and D

$$R_{GD} = \frac{400 \times 400}{400 + 400} = 200\Omega$$

$$\frac{R_{GE}}{R_{GD}} = \frac{R_{EB}}{R_{DB}}$$



(condition of balanced wheat stone bridge)

Equivalent resistance across G and B

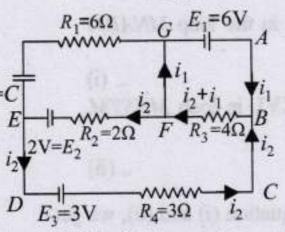
$R_{GB} = \frac{300\times300}{300+300} = 150\Omega$ ∴ Current $I = \frac{V}{R_{GB}} = \frac{10}{150} = \frac{1}{15}$

Current $\frac{I}{2}$ further divides into two equal parts at M.

Hence potential difference across the voltmeter

$V_G = IR = \frac{I}{4}\times 400 = \frac{1}{15}\times\frac{400}{4} = \frac{20}{3} = 6.67\text{ V}$

22.



Applying Kirchhoff's law in loop $ABFGA$

$6-(i_1+i_2)4=0$ ... (i)

Applying Kirchhoff's law in loop $BCDEFB$

$i_2\times3-3-2+2i_2+(i_2+i_1)4=0$ ... (ii)

Putting the value of $4(i_1+i_2)=6$ in eq. (ii)

$3i_2-5+2i_2+6=0$

∴ $i_2 = -\frac{1}{5}A$

Substituting this value in eq. (i), we get

$i_1 = 1.5-\left(-\frac{1}{5}\right) = 1.7\,A$

Hence, current in $R_3 = i_1+i_2 = 1.7-0.2 = 1.5\,A$

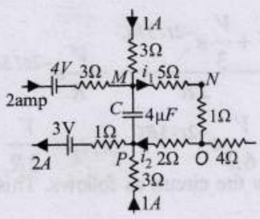
Across the capacitor potential difference,

$V_E-2-0.2\times2 = V_G$ ∴ $V_E-V_G = 2.4\,V$

∴ Energy stored in capacitor, U = $\frac{1}{2}CV^2$

$= \frac{1}{2}\times5\times10^{-6}\times(2.4)^2 = 1.44\times10^{-5}$ J

23. Applying Kirchhoff's first law, at junction M, and P current $i_1 = 3A$ and $i_2 = 1$A respectively.



At steady states, no current flows through capacitor

Moving the loop along MNO to P

∴ $V_M-5\times i_1-1\times I_1-2\times i_2 = V_P$

∴ $V_M-V_P = 6i_1+2i_2 = 6\times3+2\times1 = 20\,V$

∴ $V = 6\times3+2\times1 = 20\,V$

Energy stored in the capacitor

$U = \frac{1}{2}CV^2 = \frac{1}{2}\times4\times10^{-6}\times20\times20 = 8\times10^{-4}$ J

24. Resistance of 2Ω and 3Ω are in parallel

$(R_{eq})_{AB} = \frac{2\times3}{2+3} = 1.2\,\Omega$

Net current through the battery, $I = \frac{6}{1.2+2.8} = 1.5\text{A}$

$\because P, d$ is same ∴ $2I_1 = 3I_2 \Rightarrow I_2 = \frac{2}{3}$

$I_1+I_2 = I_1+2I_1 = 1.5$ ∴ $I_1 = \frac{3}{5}\times1.5 = 0.9A$

25. Given P.d. across the 400 Ω resistance = 30 V.

∴ $P.d.$ across the 300 Ω resistance = 60 – 30V = 30 V.

As the voltmeter is in the parallel with the 400 Ω resistance, so their combined resistance

$R' = \frac{400R}{(400+R)}$ (Here R = resistance of voltmeter)

Here R' = 300Ω, as the potential difference of 60 V is equally shared between the 300 Ω and 400 Ω resistance.

∴ $300 = \frac{400R}{(400+R)} \Rightarrow R = 1200\Omega,$

i.e., The resistance of the voltmeter, R = 1200Ω. When the voltmeter is connected across the 300Ω resistance, their combined resistance

$R'' = \frac{300R}{(300+R)} = \frac{300\times1200}{(300+1200)} = 240\Omega$

∴ Total resistance in the ciruit = 400 + 240 = 640 Ω

∴ Current in the circuit

$I = \frac{V}{R} = \frac{60V}{640\Omega} = \frac{3}{32}A$ ∴ Voltmeter reading

= Potential difference across 240 Ω resistance

$= V = IR'' = \frac{3}{32}\times240 = 22.5V$

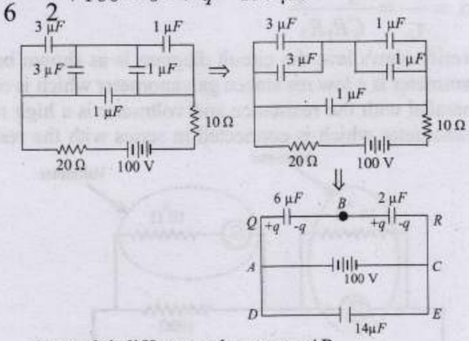
26. Inside the battery, current flows from the positive terminal to the negative terminal of the battery.

During charging, the potential difference between the two terminals of the battery.

$V = E+Ir = 2+5\times0.1 = 2.5\,V$

27. Applying Kirchhoff's law KVL in loop $AQBRC$

$-\frac{q}{6}-\frac{q}{2}+100 = 0 \Rightarrow q = 150\,\mu C$



∴ Potential difference between AB,

$V = \frac{q}{C} = \frac{150}{6} = 25V\,(V_{AB})$

∴ Potential difference between BC

$V_{BC} = 100-25 = 75V$